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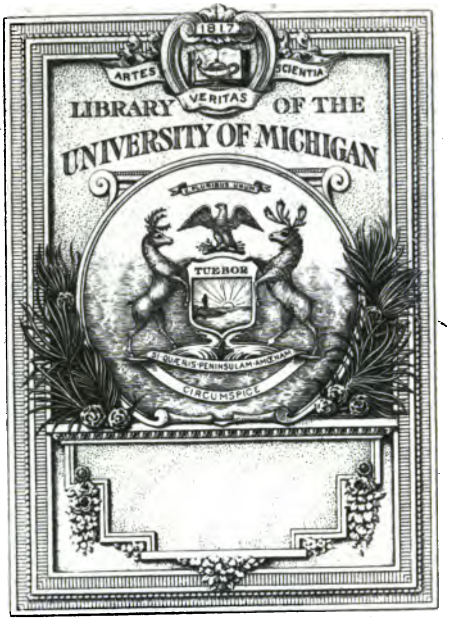
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THE EFFECTS OF ELECTRICITY

IN

Paralytic and Rheumatic Affections, Gutta Serena, Deafneſs, Indurations of the Liver, Dropſy, Chloroſis,

AND MANY OTHER

FEMALE COMPLAINTS, &c.

ILLUSTRATED WITH

A VARIETY OF CASES

WHICH HAVE OCCURRED AT THE

MEDICO-ELECTRICAL ROOMS,

No. 10, LEICESTER-STREET, LEICESTER-SQUARE.

To which are added,

SOME OBSERVATIONS ON THE

INEFFICACY OF METALLIC TRACTORS;

AND

AN ANALYSIS

OF A

COURSE OF LECTURES

ON

EXPERIMENTAL PHILOSOPHY.

BY C. H. WILKINSON, SURGEON.

London:
PRINTED FOR M. ALLEN, 15, PATERNOSTER-ROW.

1799.

TO

SIR WALTER FARQUHAR, Bart. M. D.

THE FOLLOWING

ESSAYS

ILLUSTRATIVE OF THE

BENEFICIAL EFFECTS

OF

ELECTRICITY,

IN A

VARIETY OF COMPLAINTS,

ARE MOST RESPECTFULLY INSCRIBED,

No. 10, Leiceſter-Street,
Leiceſter-Square.

6-22-34, MRJ

ERRATA.

Page 33. l. 8. *was* removed, read *were* removed.
—— 41. l. 19. *lui dedie*, read *ter de die*.
—— 54. l. 15. *elaſtic*, read *inelaſtic*.
—— 57. l. 20. *pairs*, read *hairs*.
—— Do. l. 26. *Tumo*, read *Tumor*.
—— 58. l. 5. *bnnting*, read *bunting*.
—— 61. l. 16. *Unq*. read *Ung*.
—— 63. l. 13. *Inculation*, read *Inſulation*.

ANALYSIS.

Page 79. l. 3. ON THE, read OF THE.
—— 80. l. 3. *produce*, read *produces*.
—— 85. l. 11. *Animal*, read *Mineral*.
—— 94. l. 14. *Bongouer*, read *Bougouer*.
——105. l. 27. *exerts*, read *exert*.
——109. l. 15. *Tripolium*, read *Trifolium*.
—— Do. l. 16. *Lichen vertrillatus*, read *verticillatus*.
——122. l. 19. *meniſeus glaſs*, read *as a watch glaſs*.
——122. laſt l. *plane convex*, read *plano-convex*.
——133. l. 13. *Lieberkulen*, read *Lieberkuhn*.
Ditto l. 20. Ditto Ditto.
——164. l. 7. *infringes*, read *impinges*.
——168. l. 7. *Schenchzer*, read *Scheuchzer*.
——195. l. 12. *ſays*, read *ſay*.

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MEDICAL ELECTRICITY.

THE benefical effects which have been experienced by the application of Electricity in a variety of diſeaſes, render it neceſſary for every practitioner to medicinally examine this pervading principle.

As the knowledge of this branch of philoſophy is yet in its infancy, it requires the united obſervations of many individuals before its influence on our organization can be well aſcertained. Every complaint in which it may be advantageouſly employed ſhould be accurately characteriſed, and its effect in every ſtage of the diſeaſe carefully ſtated.

With ſuch a profeſſional conſideration, Mr. Wilkinson, Surgeon, has fitted up at his Houſe, N° 10, *Leiceſter-Street, Leiceſter-Square,* an appropriate and extenſive Apparatus: by employing Electricity on ſo large a ſcale, he flatters himſelf he ſhall hereafter be enabled to make ſome uſeful inferences.

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PREFACE.

THE effects of Electricity in the cure of diſeaſes being by ſome diſputed or even denied, it becomes an object worthy of enquiry what credit is due to ſuch inſinuations, and whether the truth of the remark, if admitted, may not be found to ariſe from ſome irregularity or neglect in the mode of its adminiſtration. As an agent in nature few will deny its influence; and the experiments which have been made by Ingenhouze, Beccaria, Bohadſch and others, ſufficiently evince its effects on animated matter. With regard to its medical utility, a variety of caſes may be adduced in illuſtration of its effects, and in teſtimony of its ſalutary and ſucceſsful application, where the moſt celebrated and powerful medicines have been unprofitably employed. How then, it will naturally be aſked, is the uſe of that remedy diſcontinued or at leaſt neglected, when ſo much can be ſaid in its favour? I reply to this queſtion, by admitting that in a variety of complaints it is of no uſe, and that even in thoſe inſtances where it may be with propriety recommended, it can afford no relief unleſs judiciouſly applied. We can certainly not be at a loſs to account for its being conſidered a precarious remedy, when we recollect how often it is entruſted to perſons who are not acquainted with Anatomy or with diſeaſes, and whoſe practice may be comprehended in this ſentence, "I electrify "patients;" or who can perhaps add to the liſt of their qualifications bleeding, cupping, and all operations of the Teeth. I beg I may not be conſidered as having any * perſonal alluſion in making this remark, which proceeds from daily obſervation of theſe circumſtances. At preſent there are many practitioners in this metropolis well acquainted with their profeſſion, who have applied Electricity with propriety and ſucceſs. Mr.

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* We may venture to blame even ſome judicious practitioners for their inaccuracy in this reſpect, for moſt writers on this ſubject have contented themſelves with ſaying, "Electricity was applied," inſtead of mentioning the mode or the continuance; whereas it is certain that it varies according to the manner in which it is applied, as much as any two medicines in the materia medica.

Birch has enriched the records of medicine with many uſeful facts and obſervations relative to this ſubject, and ſhewn by ſome practical arguments the efficacy of this principle; and Mr. Abernethy has bore teſtimony to its utility in caſes of Pſoas Abſceſs, &c. As there is ſtill ample latitude for further enquiry, every thing which can contribute to extend its uſe, it is preſumed, will be received with approbation, by which perſuaſion I am induced to inform the public of an eſtabliſhment, which has been particularly conſtructed with this view. In order to adminiſter Electricity with more regularity and ſucceſs, we have compleated an apparatus with conſiderable expence, and by the aid of a variety of inſtruments, are enabled to apply it in any requiſite manner and with any degree of power; and as we always keep an exact regiſter of the hiſtory and progreſs of the diſeaſe, we are capable of aſcertaining its amendment with exactitude and preciſion. The following caſes will, I truſt, evince the advantage of this undertaking, and add ſomething to the code of practical intelligence; and we ſhall feel obliged to thoſe who will favor us with any communications which may improve the ſubject.

AN ESSAY ON THE MEDICAL EFFECTS OF ELECTRICITY.

IT would exceed the limits and intention of this ſmall publication to enter into an extenſive and critical enquiry of the different publications which have been delivered on the effects of Electricity in the cure of Diſeaſes; nor would it be a very profitable employment to the reader to recapitulate thoſe facts which are recorded in others, however it may be right to premiſe its general effects previous to the inſertion of caſes, which will be the beſt confirmation of our remarks. Every one knows almoſt the effect which is produced; when an accumulated portion of this fluid is ſent through the body, it agitates the frame in ſpite of the moſt determined reſolution; when applied in a diminiſhed ſtate of accumulation to the ſurface of the ſkin, for ſome time it excites a degree of redneſs or inflammation; hence its ſtimulating properties are well known, and many who recommend its uſe attribute its ſucceſs to this principle; they conſider it more powerful becauſe more penetrating than other applications of a ſtimulating or rubefacient nature. This ſuppoſition does not appear to be juſt, as it has often been beneficial in caſes where it has been applied without any ſenſible ſtimulus, and indeed admitting the opinion to be true, that the human body is ſo replete with electricity, that no additional quantity can be added without diſpoſſeſſing that which was previouſly contained, it will appear evident, that this idea of ſtimulus is inadequate to aſcertain its operation. But without entering any further at preſent into the examination of this hypotheſis, we will proceed to the conſideration of its effects, when adminiſtered in that form which may moſt properly be ſtyled ſtimulating, and in this common mode of its being applied, ſufficient attention has not been paid to the peculiar circumſtances of the patient.

In thoſe inſtances where there are glandular obſtructions, where there is a paralyſis of the deeper ſeated parts, or where there is an effuſion or depoſit of matter, the application of Sparks will be found generally, if not always inſufficient for the purpoſe; it is true it may here be objected that the ſtimulus is propagated from the ſurface to the ſeat of the Diſeaſe, as when a bliſter is applied to the pubis or the ſacrum for a paralyſis of the bladder, but this is not a parallel example. We know from pretty certain obſervation, that Cantharides have a ſpecific action on the urinary organs, whilſt the effect of Sparks applied to the ſame ſurface will be that of inflammation of the ſkin, and determination of blood to that part, and hence the uſe of Sparks is not only different, but ſometimes oppoſite to that of ſhocks, as we ſhall be enabled to prove by ſome inſtances.

Another mode by which Electricity may be applied, and which has not been generally introduced into practice, is by throwing off the accumulated portion of an electrical battery, not by any means by a communication with the outſide, and thereby giving a ſhock, which from an apparatus of that deſcription would be extremely hazardous, but by paſſing off the ſtream by means of a director: this application of it is extremely pungent, and if perſevered in for a few minutes, excites a conſiderable inflammation on the ſkin, hence its efficacy in removing the deeper ſeated pains, as Pleuriſy, where bliſters though very ſerviceable, are too tardy in their operations. In electrifying the ear, it is neceſſary to paſs a metallic rod through a glaſs tube, whoſe extremity is adapted to the meatus auditorius externus; this remedy is very appropriate to different ſpecies of this complaint. In that depending on a relaxation of the Membrana Tympani, it will be proper to paſs ſlight ſhocks through the temples; the moſt characteriſtic ſymptom of this ſpecies of deafneſs, is the patient hearing better when riding in a carriage, or being in any ſituation where the Tympanum can be diſtended by the impulſe of the air. In another ſpecies of deafneſs, ariſing from a diminiſhed ſecretion of the Cerumen, the application of Electricity to the internal part of the ear is wonderfully efficacious; indeed it will be very eaſy to explain this on a phyſiological principle, for as it is an axiom that, cæteris paribus, a ſecretion is increaſed in proportion to the quantity of blood determined to the part, ſo here the effect takes place, from the irritation or ſtimulus of Electricity, which if applied to a non-ſecreting ſurface would occaſion redneſs, ſo applied to a ſecreting membrane it increaſes the diſcharge; on this principle Electricity will be found uſeful in thoſe caſes where ſecretion is deficient, and where there is a degree of inaction in the veſſels of a part; hence we have adminiſtered it with ſucceſs in Ulcers of the Legs, not by applying ſparks, however, to the ſurface of the ſore, but by paſſing ſlight ſhocks thro' the leg above and below the Ulcer, applying one director to the inſide of the calf, or on any part of the gaſtrocnemius muſcle, as it will be more ſenſibly felt. It becomes of conſequence to remember, where Electricity is adminiſtered for a conſiderable length of time, as in paralyſis of the extremities, Hemiplegia, or more particularly in the paralyſis occaſioned by lead, to vary the poſition of the directors, for the paſſage of the ſhocks exactly thro' the ſame ſpot brings on inflammation and ulceration, which in ſome debilitated conſtitutions produce a diſagreeable effect. Shocks may be ſent with perfect ſafety through the brain, though not very powerful ones, for though we have inſtances of perſons having received very powerful ſhocks through the head, who have recovered from the effects, yet a repetition of the ſame violence would undoubtedly diſturb the * arrangement of that

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* Dr. Abildgaard has ſhewn by repeated experiments, the conſequences of ſending ſhocks thro' the head; in thoſe caſes, he endeavoured again to rouſe the vital powers by ſending ſlighter ſhocks in the ſame direction, yet without effect; but immediately the animal was reſtored, by paſſing ſhocks from the Sternum, to the Vertebræ.

Queſt. Does the effect of lightning on the brain, act in the ſame manner as concuſſion? and if it does, is it not probable that the beſt means of reſtoring the patient would be having recourſe to this practice of paſſing ſhocks through the Thorax in the direction of the Heart?

that organ whoſe texture we know to be ſo delicate, and whoſe functions are often more injured by concuſſion than wounds.

In the cure of that ſpecies of blindneſs called * Gutta Serena, as alſo in the Hydrocephalus internus, ſlight ſhocks ſent through the head are highly beneficial, and in theſe inſtances the uſe of ſparks is inefficacious. Some time ſince it was thought Electricity might be of ſervice in quickening the action of other medicines, or that a diſcharge of electrical fluid from a jar containing ſome particular medicine, would carry ſome portion of the medicine along with it. Dr. Franklin tried

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* Dr. Darwin recommends its uſe in thoſe caſes particularly, and alſo in cataracts, as well as ſome other affections. In the pareſis irritativa, he adviſes ſlight ſhocks ſent thro' the ſtomach; in ſparmodic affections, Epilepſy, Tetanus, &c. he applies this remedy.

Mr. Cavallo informs us of a caſe where there was an opacity of the vitreous humour, which was perfectly cured by Electricity: but he does not deſcribe the peculiar diagnortics of this caſe, or what particular manner, or for what continuance of time Electricity was applied. He adviſes as the beſt mode of application in Gutta Serena, that the fluid ſhould be drawn from the eye with a wooden point; but with all deference to his well known abilities, I muſt obſerve this mode is too mild, a Paralyſis of the Optic Nerve will require the excitement of ſlight ſhocks to reſtore its ſenſibility.

tried ſome experiments of this kind: he tried to affect the bowels by electrifying from a jar containing ſome purgative medicine, but it did not produce the effect; indeed I am at a loſs to imagine what effect could be expected to ariſe from the ſmall portion that could then have been conveyed to the ſyſtem; however though in this reſpect it will not be found effectual, it poſſeſſes a power of quickening the effect of medicines otherwiſe applied. Then if a part of the ſkin is electrified for ſome time with ſparks, and a portion of Cantharides is applied to the part, ſoon afterwards it occaſions veſication in a much ſhorter ſpace of time than it would otherwiſe have done. In glandular enlargements about the neck and other parts of the body where I have applied Electricity with very great ſucceſs, and where Bark and Steel can be adminiſtered with advantage, I am very certain I have ſeen much better effects ariſe from their combination than would have followed from either ſeparately *adminiſtered.

Nothing

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* This is a circumſtance which it is of particular conſequence to recollect, and it will certainly be found, that in a variety of caſes where it has not been ſo beneficial, it becomes a valuable auxiliary to other means: thus for inſtance, in an enlarged Teſticle where no inflammation exiſts, Mercurial Ointment has often been recommended. If this has

been

Nothing can be more comprehenſible or clear than the modus operandi in theſe caſes; when the tumors leſſen from tonic remedies, it is a conſtitutional

been continued for ſome time without accompliſhing the end it was intended, this is often laid aſide for ſome ſtimulating application; perhaps Electricity will here be employed, but this appears to me to be the defect in the regulation of the remedy. Mercury ſhould be uſed conſtitutionally, whilſt Electricity is directed to the part. A perſon taking a certain quantity of Mercury for ſome weeks, or perhaps leſs, will find his teeth looſe; it is evident therefore that abſorption is increaſed, for the alveolar ſockets have undergone a change, and it is not confined in its action to any particular part, but the alteration here is a gage to the ſtate of the conſtitution. If under theſe circumſtances the tumor does not leſſen, it is evident there is a want of action in the abſorbents of that part, and this the ſtimulus of Electricity is beſt calculated to ſupply. That there is a want of action in theſe caſes is very evident, becauſe in every part of the body, the abſorbents when in health, have the power to remove any fluid which may be depoſited, and where this proceſs does not go on, there is either a weakneſs, or a diſeaſe in this part of the lymphatic ſyſtem; in theſe caſes likewiſe there is always a loſs of ſenſation, in a greater or leſs proportion, and there can be no better criterion of the ſtate of the Teſticle than its ſuſceptibility to be affected by this principle; it will be remembered this obſervation is applied to the indolent, and not the inflamed tumor. If the directors are applied to the part of the Teſticle which is enlarged, little pain is felt in compariſon with the ſenſation occaſioned by its being directed to the ſpermatic cord.

tutional change, an increaſed action being diſtributed throughout the habit. Theſe tumors partake of it in a ratio with the reſt of the ſyſtem, but as theſe being in a ſtate of greater inactivity, will require greater excitement: that muſt be applied topically, and therefore Electricity proves ſo ſerviceable.

But perhaps it will be better to proceed to particularize thoſe complaints in which this remedy has been found ſerviceable.

We have already ſtated that Electricity is adminiſtered with ſucceſs in paralytic affections, and it is likewiſe well known that in thoſe complaints it has often proved ineffectual; in order to form a determination between theſe different reſults, and account for the uncertainty of the remedy, we ſhould carefully examine the different circumſtances under which it has been applied. We ſhall firſt then conſider

HEMIPLEGIA.

This is an affection often, if not always brought on from ſome injury done to the brain: it is well aſcertained that in ſuch inſtances the injury is on the oppoſite ſide to that which is become paralytic. This however is an obſervation that has been ſometimes contradicted: at leaſt caſes are given to prove that the hemiſphere of the brain which is affected is not the ſame with that which evinces the miſchief; however the accurate diſſection of Morgagni, Valſalva, and Aretæus, as well as of authors of ſtill more remote period, prove the truth of the former aſſertion; and as we know the nerves from their origin to their exit, at the foramina of the head decuſſate each other, the cauſe of this peculiarity is eaſily aſcertained. It may be neceſſary here to enter into ſome inveſtigation of the effects which follow from compreſſion of the brain, and conſider how far the violence of the ſymptoms are proportioned to the quantity of extravaſation, how far the extravaſation is capable of being abſorbed, and how far the brain is likely to recover itſelf when the preſſure has been removed, and whether Electricity does or does not contribute to reſtore its functions and promote the abſorption of the fluid.

1ſt. Compreſſion of the brain has ſo often been attended with fatal effects, that moſt practitioners down to the preſent time, have conſidered it abſolutely neceſſary to remove the cauſe by artificial means whenever it could be accompliſhed. The exerciſe of the trephine, even in ſlight accidents of this deſcription, were often had recourſe to, but as theſe caſes are not in the leaſt appoſite to this publication, it will be ſufficient to obſerve that the conſequences of compreſſion are not found to be ſo fatal as were imagined. I have ſeen ſeveral inſtances of this kind where no bad effects enſued, and in almoſt every collection of Anatomical curioſities, a ſpecimen may be found to authenticate this fact; in all theſe inſtances I will venture to affirm the danger will be found in proportion as the Cerebellum may partake of the injury: even portions of the Cerebrum may be removed, of which I have ſeen two remarkable inſtances. I believe it will be found that the brain will ſuffer the loſs of a portion of this ſubſtance, with leſs impunity, than it would compreſſion on the other. From the hiſtory of diſſections with which we are furniſhed, I think it probable that the fatal effects of compreſſion frequently ariſe from the interruption to the circulation through the Plexus Choroides, in thoſe remarkable caſes which have been ſo well deſcribed by Mr. Abernethy, Mr. Hill, Mr. Latta, and others, where in conſequence of an injury of the head, a fungus rapidly forms under the meninges of the brain, and by its continued preſſure, and increaſing diſtention ruptures theſe membranes; the exit to the tumor, gives relief to the patient: it originates from the rupture of ſome ſmall veſſel, and unleſs there is an opening for the evacuation of its contents, the preſſure of the fluid frequently

produce

produces death. Theſe obſervations may perhaps be conſidered as digreſſing from the profeſſed deſign of this publication, but they are adduced as inſtances of the effects of compreſſion of extravaſation, and we ſhall preſently conſider the poſſibility of extravaſation being removed, where it is limited in its extent, and confined in its cavity; but it will be right before we quit the preceding topic to remark that in thoſe caſes, the diſcharge comes on in conſequence, ſays Mr. Abernethy, of a diſeaſed ſtate of the veſſel of the brain, which occaſions them to give way. I am inclined to think ſome of thoſe fine ramifications, which conſtitute the Plexus Choroides, give way in theſe caſes. Among the number of apoplectic patients whom Morgagni examined, moſt of them were found to have died from the rupture of theſe veſſels; in ſeveral of theſe inſtances the effects aroſe without any peculiar violence being offered to the head, and therefore it points out this important inference that the tenuity of theſe parts is too ſlender to bear any conſiderable violence. This is another inſtance of the neceſſity of a medical Electrician being acquainted with the Anatomy and Phyſiology, of the human body, for if powerful ſhocks were ſent thro' the brain, under theſe circumſtances it would rupture thoſe veſſels which have ſuch tenuity of texture.

We are now then to conſider the poſſibility of extravaſation being removed. From the hiſtory of caſes we learn that perſons who have been at ſome period of their lives attacked with hemiplegia, or even with apoplexy, have not only ſurvived the accident, but have gradually recovered thoſe functions which were either loſt or leſſened. It has appeared from diſſections of thoſe perſons who have thus been attacked, that a quantity of fluid had been effuſed, and that the effuſion has been gradually abſorbed: a caſe of this lately occurred where there was a cavity in the right hemiſphere of the brain, of very conſiderable extent, and where there were ſome portions of coagulable Lymph, and other appearances which proved that the effuſion had taken place at ſome remote period; but though we are told that the patient recovered, we are not acquainted with the progreſs of amendment, ſufficient is adduced to prove the fact of abſorption going on in the brain; and tho' Anatomiſts have not been able to demonſtrate this in the human ſubject, as it has been found in fiſhes, * we may

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* Another additional evidence of abſorption, going on in the brain is this; that in caſes of Hydrocephalus externus the whole of the brain, (including the cerebellum) has been nearly removed, and yet the fluid has been perfectly tranſparent.

infer with probability from analogy, and from the before mentioned phænomena that they do exiſt. Here then it will be found, Electricity may be adminiſtered with ſucceſs, but it muſt be with theſe reſtrictions. When an Apoplexy comes on, if we are led to ſuſpect from the general appearance of Plethora in the patient, from its being brought on in conſequence of violent exertion or from a full meal, or any other collateral circumſtances which could impede the circulation of blood in the head, that is from an effuſion of blood within that cavity; we ſhould diſcontinue the uſe of this remedy, till other means have been adopted to remove the cauſe, or guard againſt a repetition of the attack: it is only when the complaint appears to be ſtationary, that it can be judiciouſly applied. Slight ſhocks paſſed thro' the head haſten the cure, as well by *promoting the abſorption, as by reſtoring that †ſenſibility

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* Mr. Bell, ſpeaking of the effects of concuſſion, ſays, "when from ſhocks given to the brain, much langour, inactivity, and loſs of memory, have continued more permanent than uſual, Electricity has been productive of good effects."

Vide SYSTEM of SURGERY, Vol. 3. Page 144.

† From many obſervations, it is proved, that when a bone has been ſlightly depreſſed, it has recovered its ſituation by degrees. Is it neceſſary for the brain to recover its ſituation, for the patient to recover his perfect ſenſes; that is ſuppoſing at firſt this compreſſion interrupted them, or does the brain recover its functions without recovering its ſituation?

and action of which from compreſſion it was deprived. As an illuſtration of thoſe remarks, we ſhall add the following caſe.

CASE I.

A gentleman about forty years of age, who from his habit of life had been accuſtomed to uſe much exerciſe, complained when ſitting down after dinner of a violent pain in his head, which came on ſuddenly; it continued without abatement till night, when on attempting to get up ſtairs he fell down, and was taken up almoſt in a ſtate of inſenſibility; he was put to bed, and continued in a ſtate of coma, with ſome ſlight degree of the apoplectic ſtertor. As ſoon as medical aſſiſtance could be procured, blood was drawn from the arm, to the quantity of fourteen ounces, by which he was evidently relieved; an emetic was afterwards given, which operating very well, relieved his ſtomach from that collection of aliment which in all probability was the occaſional cauſe of his indiſpoſition; * a bliſter was applied to

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* The application of a bliſter to the nape of the neck, is a very common, and generally beneficial practice; but it is not by the evacuation it produces, but the ſtimulus it excites, that it produces its ſalutary effects.

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the neck, and at night his feet were put in hot water, and a draught with ſome Sp^{s}. Minder. and Tinct. Opii given him, his pulſe was ſomewhat full, and beat about a hundred in a minute; he continued tolerably well during the night, and next morning ate a ſlight breakfaſt. As ſoon as he began to revive from that ſtate of general inſenſibility into which he at firſt fell, it was found that a hemiplegia had affected the right ſide, rendered him incapable of moving the arm or leg on that ſide; in a few days the feveriſh ſymptoms were removed, and he was aſſiſted to get out of bed: the complaint now was become chronic, and ſtimulating applications were had recourſe to. Bliſters were applied and repeated, and muſtard volatile liniment and other medicines of the rubefacient claſs, continued for ſome time. In the courſe of nine or ten days from the commencement of the fit, he was ſo far recovered as to be able to move his right leg and thigh, throwing it forward in a circular manner. From this time no further amendment was obſervable, for a fortnight following, though the ſame plan of treatment was ſtill uſed; at this time he begun the uſe of Electricity; a dozen ſlight ſhocks were ſent through the head, the directors being applied to the temporal bones as well as from the occiput to the os frontis, an equal number of ſhocks were ſent through the upper and lower extremity of the ſame ſide; he ſubmitted to this treatment with alacrity, and declared he found himſelf capable of exerting his leg with greater facility ſoon after the firſt application; it was continued regularly every day, and with gradual but unremitted ſucceſs, the uſe of the lower extremity becoming every day more perfect. After a week's perſeverance, a tickling ſenſation took place in the arm, it by degrees became more capable of action, and in the ſpace of two months the patient recovered; the only difference being, as he thinks, a ſlight deficiency in his powers of recollection.

There is nothing particular either in the ſingularity or the ſucceſs of this caſe. Did theſe ſymptoms come on in conſequence of extravaſation of fluid in the head, or diſtenſion of the veſſels? The principal circumſtance to be attended to is the efficacy of ſhocks ſent through the head, the patient was as far recovered from the uſe of ſtimuli to the ſkin during the firſt fortnight, as he could be; but it was neceſſary ſome excitement ſhould be applied to that organ where the powers of life more particularly reſided. It may be aſked how long after an attack of hemiplegia may Electricity be applied with a probability of ſucceſs? to this no preciſe reply can be offered: but from the ſucceſs which has attended its uſe, even in long continued paralyſis, I would recommend its uſe in all thoſe caſes where there is not a conſiderable diminution in the ſize, as well as flaccidity in the part.

The following caſe, which is more remarkable in its peculiarities, and ſtill more ſucceſsful in the recovery, will tend to evince the efficacy of this fluid in reſtoring the intellectual power.

CASE II.

A young woman in Weſtminſter, who was delivered of a child without any uncommon circumſtances in parturition, was ſeized about three weeks from that period with inflammation in the right breaſt; the inflammation, either from neglect or ſome other cauſe, continued to increaſe, and terminated at laſt in an abſceſs of that part. The violence of the complaint, the debility of her conſtitution, and perhaps the anxiety of her mind, had reduced her to a ſtate of conſiderable emaciation. The fever which had been brought on was followed by delirium, and in the ſtate of convaleſcence, which was the time when I ſaw her, this intellectual derangement continued. There was a wild ſtare in her countenance, and her behaviour betrayed ſome marks of apprehenſion and timidity; when aſked any queſtion ſhe made no reply, or only very conciſe and unſatisfactory one. As the feveriſh ſymptoms were entirely removed, and her conſtitution was conſiderably reduced, ſhe was recommended a generous diet, and took at the ſame time ſome ſtomachic medicines. Under this plan of treatment her health began to amend, but the ſame ſtupidity and idiotiſm continued. About five months from the commencement of her complaint ſhe began the uſe of Electricity. In conſequence of the diſeaſe which had reduced her, it may eaſily be gueſſed the child was incapable of being ſuckled by the mother; it was accordingly weakened, and ſhe had never had any return of the menſtrual evacuation from the period of parturition, till now. I adminiſtered ſome ſlight ſhocks through the head, and likewiſe paſſed ſome through the pelvis, applying the ſhocks from pelvis to ſacrum. In thoſe which were ſent through the head, the Electrometer was at the diſtance of one quarter of an inch, but in thoſe through the pelvis the diſtance was greater; the effect was unexpectedly beneficial. The very next day, the menſtrual diſcharge came on, her head was conſiderably relieved, her appearance altered, and her converſation became more rational; ſhe has continued in a ſtate of amendment ever ſince, her appetite is much improved, and her general health much reſtored. In this caſe I conſider it was abſolutely neceſſary to direct ſhocks through the head and pelvis, that at the ſame time that the menſtrual diſcharge was incurred by an application to that part, the energy of the brain might be reſtored, by a ſtimulus directed to that organ. In relating the hiſtory of this caſe, particular notice was taken of the inflammation of the breaſt, the ſecretion of milk had here completely formed, and we are to conſider the ſudden check to ſuppreſſions of this ſecretion as being in a principal degree acceſſary to the ſubſequent ſymptom.* It will be ſuperfluous to adduce caſes in order to evince the utility of Electricity in theſe and ſimilar affections of the head; future experience and further obſervation are requiſite to ſhow to what extent this benefit may be derived, and what are the reaſons which ſometimes render its uſe unſucceſsful. We ſhall now proceed to conſider a complaint, which as it often proves ſuperior to every medicine or means employed, and is in its effects extremely important, requires every effort of the practitioner to check its progreſs or obviate its conſequences. We allude to Gutta Serena, or what is more deſcriptive of the nature of the complaint, a paralyſis of the optic nerve; this is generally ſlow in its progreſs, and when taken in the commencement of its career, may be often cured. We are not well informed with regard to that peculiar alteration of the brain which gives riſe to this infirmity; the illuſtrious Morgagni, to whoſe records we appeal on moſt occaſions for anatomical truths, has given us no information on this ſubject: it is not improbable that it frequently originates from ſome preſſure on the optic nerve. We know ſeveral inſtances where * tumors which occupy part of the ſocket of the eye, occaſions this complaint, and the gradual accumulation of any fluid in the anterior part of the brain, may likewiſe prove the ſource of this malady. We ſhall not attempt to enumerate the different remedies which have been recommended, or enter into a critical examination of the ſuperiority of the different modes of treatment. The uſe of ſternutories are often ſalutary, and mercury given for a continued time, that is to ſay, for ſome weeks, in ſuch quantity as to keep up a ſlight ſalivation, is perhaps of all internal medicines the moſt efficacious and certain; but we are to ſpeak of Electricity, whoſe ſalutary operation will be evidently exhibited in the following inſtance.

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* Puzo has written with peculiar ſagacity on this ſubject, and deſerves well to be conſulted.

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* It is worthy of remark, ſays Dr. Baillie, that when tumours of any kind preſs upon the thalami nervorum optic, or the optic nerves themſelves within the cranium, viſion becomes impaired in various ways; and that when tumours preſs upon the tuberculum annulare, or the medulla oblongata, convulſions are very apt to occur.

A woman about forty years of age, who had as yet found no particular abatement or irregularity of the menſtrual diſcharge, complained of a conſiderable dimneſs and imperfection of ſight; the dimneſs was moſt prevalent in the morning, when ſhe aroſe a confuſed appearance of nubeculæ formed, as it were, an obſcure atmoſphere, which continued about five or ſix minutes before it entirely diſperſed. When ſhe found this inconvenience increaſing, ſhe applied to a ſurgeon, who judiciouſly recommended a ſeton in the neck; this was continued for ſome time, and ſhe flattered herſelf at firſt with the expectation of permanent advantage, in the ſpace of a month from the ſeton. She however was convinced of her being worſe, objects not being ſo diſcernible. She now begun the uſe of calomel with ſternutories, which ſhe perſevered in for three weeks, without obtaining the relief ſhe wiſhed: ſhe now added the power of Electricity to the medicines above mentioned. Having ſlight ſhocks paſſed through the temples, theſe occaſioned a plentiful ſecretion of tears on each time of their adminiſtration, and in about ten days perceptible benefit was received. The ſame remedy was continued and increaſed; at firſt only a dozen ſlight ſhocks were adminiſtered, within a fortnight they were gradually multiplied to fifty, and the patient finding the utility of the remedy, continued it for five weeks, being ſo far recovered as to imagine its further uſe unneceſſary.

It is poſſible ſome may be inclined to attribute the event of this caſe to the medicines which were employed, but as they produced no evident amendment till combined with Electricity, it is certainly fair to aſcribe a greater influence to its ſalutary operations.

SCROPHULOUS TUMORS.

A VARIETY of caſes may be adduced to ſhew the effect of Electricity in curing theſe affections; but as ſeveral are on record, as well as of other glandular indurations, we ſhall ſelect only one or two from thoſe which have come under our own inſpection, previouſly ſtating what we conceive to be of conſequence in adminiſtering this remedy to thoſe complaints. The ſame obſervation we had occaſion to make before with regard to the combination of other means, will apply here; for as theſe ſwellings only evince the peculiarity of the ſyſtem, conſtitutional remedies may at the ſame time be employed; but it is very certain, that even without any additional aid, Electricity alone is ſufficient, as will be ſhewn by one of the caſes which we ſhall deſcribe. The moſt effectual method of employing this principle here, is by paſſing ſhocks through the tumor; ſparks are very inadequate to the purpoſe, and rather tend to counteract than accompliſh our wiſhes, as muſt be obvious even from reaſoning a priori; for if there was a deep ſeated inflammation going on internally we ſhould attempt to relieve it by bliſtering or ſtimulating the ſurface; and how is it probable this can be beneficial where our principal object is to occaſion that action which is deficient?

When ſhocks of conſiderable ſtrength have been directed through the tumors, they ſometimes become painful and inflame, and then it becomes neceſſary to leſſen the excitement by omitting the repetition, or at leaſt leſſening the force of the remedy leſt they ſhould go on to ſuppurate, as it is well known theſe caſes are very obſtinate and troubleſome.

A gentleman in Soho Square who had for ſome years theſe ſubmaxillary glands enlarged, finding them increaſed in ſize, begun the uſe of electricity on my recommendation; they were at the time of his commencing this practice about the ſize of an egg, one under each jaw, but that on the left ſide was the largeſt. At firſt, ſparks were applied of conſiderable ſtrength all over the ſurface of the tumors; but the ſkin was ſo irritable they occaſioned much pain and excited an eruption like that occaſioned by nettles. It was continued in this form (that is, in the form of ſparks) for upwards of a week without the leaſt apparent diminution of bulk, or ſoftneſs in its ſubſtance. Shocks were now adminſtered, the Electrometer being the ſixth part of an inch diſtance; 50 were firſt given, and every day a gradual increaſe in ſtrength and number; the tumors ſoon ſoftened, leſſened, and was removed in a month. Towards the latter end of this period, however, the patient took ſome bark twice a day.

CASE III.

A young gentleman about ſixteen years of age who had tumors of the ſame deſcription, and nearly the ſame ſize; and who had not uſed any remedy for their removal, begun the uſe of Electricity under our care; ſhocks were immediately employed: any milder mode of adminiſtration being found unneceſſary. And it was remarkable to obſerve the difference in the conſtitution of this patient. Shocks twice as powerful as thoſe employed in the preceding caſe, had not an equal effect; ſuch was the torpor and inſenſibility of the part. Yet this patient was perfectly cured in ſix weeks without uſing a ſingle remedy beſides.

Hence, this remedy may be uſed with very great advantages in ſcrophulous, ſchirrous, and glandular tumors, its ſtrength muſt be regulated according to the ſuſceptibility of the part and the nature of the diſeaſe. In thoſe tumors likewiſe which are enlargements of the Burſæ Mucoſæ, it will be found ſerviceable, but it muſt here be very powerful, or it will have no effect. Some Surgeons recommend a blow to be given with ſufficient force to rupture the ſore, and this has often ſucceeded; the contents being diſperſed and abſorbed, but a powerful Electrical blow will be more efficacious. In the Med. Commentar. is a remarkable caſe related by Dr. Eaſon, where a hard ſchirrus of the left breaſt which had reſiſted every means, and was about to be cut out, was accidentally cured by a ſtroke of lightning. The ſhock muſt here have been very powerful, as ſhe was ſtruck down; but in two days the tumor which had been hard for months, became ſoft and ſoon diſperſed.

We ſhall now proceed to conſider another complaint which is very general, and we may add, very important, and if on any occaſion in Phyſic it be admiſſible to ſpeak with certainty and conviction, we would venture to affirm, the ſuperior and almoſt ſpecific effect of Electricity in the treatment and cure of *Amenorrhœa*, or *obſtructed Menſes*. But I do not mean to ſay that in every inſtance of this affection it will be efficacious, or even proper: but that in thoſe peculiar ſituations to which it is adapted, it is the moſt powerful deobſtruent, and ſalutary remedy; and as theſe caſes require ſome diſcrimination, we may be permitted without inconſiſtency, to make ſome obſervations on a complaint of ſo much conſequence to the female ſex.

Theſe are complaints which depend on a greater variety of cauſes than the obſtruction or impediment to the menſtrual diſcharge, but the more important variations may be reduced to two ſpecies; the one, where there is a deficiency of tone in the general habit, and an impoveriſhed ſtate of the blood: the other where the conſtitution is not defective, but where, notwithſtanding the blood is ſufficiently ſupplied, there is an impediment to the menſtrual diſcharge which is generally, if not always a local affection. There is a conſiderable difference with regard to the facility with which this action is performed in different women; but in all, the principal inconvenience is experienced at the commencement of this change. This is an effect which experience teaches us is uſual, and we cannot be ſurprized at the fact; for when a new proceſs takes place in the conſtitution to which for twelve, fourteen or ſixteen years it has never been accuſtomed, it is very natural to imagine the alteration ſhould be attended with more or leſs derangement. When the parts which are concerned in this proceſs, readily accommodate themſelves to the change, the inconvenience ſoon diminiſhes, and the patient fortunately paſſes a period always critical, and ſometimes dangerous; but when the progreſs is leſs favourable, when the age, the habits, and the ſymptoms of a female betray unequivocal marks of this alteration, without terminating ſo ſpeedily or deſirably, ſome medical aſſiſtance becomes neceſſary and eſſential. We are to conſider then particularly the influence which may be derived from Electricity under theſe circumſtances, but no deciſive rules can be advanced, till we have made ſome diſcriminations between thoſe caſes where its uſe will be ſucceſsful or precarious.

When a young perſon at the uſual period of this effect, complains of pain in the back and loins, attended with head-ache, pulſation of the arteries, and more eſpecially bleeding at the noſe, or any other part of the body, we have little room for doubting the cauſe of her indiſpoſition. What then is neceſſary to be done? under ſome circumſtances we are authoriſed to bleed, whilſt under others bark, ſteel, and other tonic medicines are employed. It is evident two modes of practice ſo oppoſite in principle, muſt be oppoſite in effect, and cannot be with indifference made uſe of in either ſtate; to diſcriminate and diſtinguiſh theſe affections, it will be important to obſerve, whether the patient is of a full habit and of a florid complexion, or whether ſhe is pale, languid, and debilitated, whether her pulſe is full and hard, or whether it is weak and frequent. Under the former ſymptoms, the full habit, the florid complexion and the hard pulſe, no remedy can be ſo judiciouſly adviſed as drawing blood either from the arm or the foot, and in addition to this the uſe of the pediluvium may likewiſe be combined; but this treatment is often unſucceſsful. The uterine veſſels have at times reſiſted theſe efforts, and not permitted that evacuation which is neceſſary to remove the inconvenience. Here then nothing can be ſo effectual as the uſe of Electricity; the force of the contained fluids is inſufficient to overcome the reſiſtance of its veſſels, it requires ſome additional ſtimulus, and it requires moſt eſſentially the application of a ſtimulus to theſe parts themſelves; medicines which would give a ſtimulus to the whole conſtitution, would not be found to anſwer, nay, they will be injurious, becauſe the increaſed action may attack other parts, and occaſion inflammation in other organs of the body. This is the caſe with regard to the lungs in particular, an accumulation of blood in that viſcus will be the conſequence, and from the great number of its blood veſſels, an inflammation will be very liable to occur; but if there is a prediſpoſition, that is to ſay, if the ſize of its veſſels are not enlarged proportionably * to the blood it was intended to tranſmit, this inflammation will be almoſt inevitable; hence the neceſſity of having a ſtimulus particularly directed to the part.

The rigidity or contraction of the veſſels of the uterus, in ſome caſes of obſtructed menſes, is very evident and very remarkable. Nothing is more common than a diſcharge from the noſe; frequently the patient is relieved by a diſcharge from other parts; the piles often follows ſuppreſſion. I have known perſons who have had a ſore on the leg ſuffer a periodical diſcharge of blood from that outlet, and ſimilar caſes are recorded by authors. We have well authenticated

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* This is the reaſon why narrow and confined cheſts diſpoſe to pulmonary complaints, there not being a free paſſage to the blood through the lungs. Some are of opinion that this formation of the cheſt does not affect the lungs, becauſe, ſay they, the lungs is proportionably leſſened, ſo as to correſpond with the cavity. But we ought to recollect that it is not coincidence between the lungs and the cheſt, but between the lungs and the conſtitution; for as all the blood paſſes through the lungs, it muſt be liable to accumulation and diſtenſion, unleſs that part is adapted to the quantity.

facts likewiſe of perſons in this ſituation having a diſcharge from the point of the fingers, and even the hair of the head. Theſe teſtimonies will be ſufficient to ſhew the degree of rigidity and obſtruction to the uterine veſſels, and how inſufficient the uſual means muſt prove in ſuch inſtances. But with regard to Electricity, it is a ſtimulus ſui generis, it can be adminiſtered with the greateſt exactitude and preciſion; it can be increaſed in its powers to any requiſite intenſity, and it can be regulated in its application to any preciſe or particular point. Theſe are effects too obvious to be denied, and the benefit reſulting from them we ſhall afterwards confirm by the ſtrongeſt and moſt unequivocal teſtimony, the teſtimony of facts. We are now only endeavouring to eſtabliſh its ſuperiority by an appeal to every underſtanding, and by obſervations too clear for any capacity not to comprehend. The influence of Electricity in theſe affections is not aſſignable to one ſingle modus operandi, its effects are multiplied. By its ſtimulus, when in a ſlight degree applied, it occaſions a peculiar determination to the pelvis, and in particular to the womb; it likewiſe aſſiſts a determination that may previouſly have been directed thither, to overcome the reſiſtance of the ſolids, and it relaxes that ſpaſm which in many inſtances is the cauſe of this reſiſtance in the ſolids.

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This effect will be ſufficiently evident, from recollecting that it diminiſhes and allays ſpaſm in other parts of the body, and that this is a cauſe in uterine obſtruction, is unqueſtionable; becauſe perſons who have had an obſtruction to the diſcharge for a conſiderable time, and who have tried powerful forcing medicines without effect, have been at once relieved by ſimple electrization; that is to ſay, without ſhocks, without ſparks, or any other ſenſible ſtimulus, but from being charged with the fluid on an inſulated chair; and here the neceſſity of diſcriminating the cauſes muſt be further evinced. When then a patient labours under the ſymptoms we have already enumerated, Electricity ſhould be had recourſe to. But where the ſource of the diſorder is of a different deſcription, where the habit is defective, Electricity cannot be adminiſtered with propriety: we muſt then firſt direct our attention to reſtore the conſtitution, at leaſt this ought firſt of all to be done; if this proves inſufficient, that is, for inſtance, if a perſon of a chlorotic habit, being under the influence of chalybeate and tonic medicines for ſome time, has not a return or appearance of this evacuation, a few ſlight ſhocks of Electricity through the pelvis will greatly aſſiſt this intention, and when the general health is ſo far amended as to favor this deſign, a ſtimulus to the uterus itſelf completes the cure: but when previouſly applied, cannot produce the effect. The following caſe will be the beſt illuſtration of theſe remarks.

A lady at an early period of her life was affected with thoſe ſymptoms which generally precede the menſtrual period, ſhe had frequent fluſhing in her face, pain in the loins, head-ache at different times, and ſickneſs at the ſtomach; theſe ſymptoms would diſappear for ſome time, until a freſh exacerbation took place, which correſponded in the periods of its return with the menſtrual evacuation. A plan of treatment, judiciouſly adapted to the nature of her ſymptoms, was preſcribed; ſhe was ordered to put her feet in hot water, to take moderate exerciſe, and chalybeate medicines were preſcribed; ſhe continued this treatment without the benefit ſhe expected for a fortnight. The following was added to her remedies: ℞ Tinct. Aloes ʒj Mirt. Camp. ℥vij & M. cap. Coch. ij lui de die. Even this proved inſufficient, and her ſtomach was unwilling to perſevere in any further trial of medicines; ſhe begun the uſe of Electricity. Twenty ſlight ſhocks were ſent through the pelvis; this was not begun at the time when ſhe expected to be out of order, and therefore no immediate alteration was produced; for this reaſon the ſhocks were very ſlight. In ten days, from the uſe of Electricity, her painful ſymptoms returned the pain in the loins and back was conſiderable:

and in order to compoſe the conſtitution, ſhe took the following draught: Tinct. Opii gutt. xxx Aq. Menth. Pimp. ℥ji Aq. Comm. ʒj. The following morning Electricity was adminiſtered more powerfully, and the diſcharge came on the very ſame day.

This caſe is mentioned, not from its ſingularity, but as a comment on the practice we previouſly recommended. In this inſtance it is ſufficiently obvious the fault did not originate in the ſyſtem in general, but in the uterus particularly. The regular return of thoſe ſymptoms which indicated an approach of the menſes, ſhewed that the conſtitution had prepared the change, but it required the aid of Electricity to complete that proceſs in which the uterus was deficient. This is a very good rule for diſcriminating wherein the fault is principally ſituated, for when there is a concurrence of thoſe ſymptoms which we have above deſcribed, theſe continue a few days, and then go off, returning again at a regular period, accompanied more eſpecially with a ſenſe of weight or bearing-down; we may reſt ſatisfied the uterus is the part to which we ſhould particularly direct our attention.*

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* It may not be unneceſſary or unſeaſonable to make an obſervation on this part, as it will point out to parents a circum-

The caſe we mentioned above, was one of that deſcription where ſome reſiſtance to the diſcharge of the fluid was to be overcome by Electricity, and not where there was a general fault in the habit; but there are other diſtinctions to be attended to. In what are called a cachectic habit, in chlorotic caſes there is always a deficiency in this reſpect. We have previouſly obſerved that the

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circumſtance which they are not ſo likely to know or attend to; but when a female, who bears no appearance of ill health, has theſe regular returns of pain without any diſcharge, if in the intervals ſhe is tolerably well, and after frequent returns of this ſort, finds a ſenſe of weight about the uterus, with a bearing down, there is reaſon to ſuſpect ſome malconformation of the parts forming an obſtacle to the fluid, which has no doubt been properly diſcharged by the conſtitution, but required an outlet. An enquiry of this kind would ſave the patient a great deal of unneceſſary pain and inconvenience, for it muſt be evident that Electricity or any other remedy would prove ineffectual, becauſe in ſome inſtances the parts have been ſo altered from their natural make, the hymen has been found, not only imperforate, but even an inch thick, forming a ſolid fleſhy ſubſtance; ſurgical aid can alone contribute to the patient's recovery. Theſe caſes, which every now and then happen, have proved that there was no fault in the conſtitution, for the fluid has been found in very conſiderable quantities, and proportionate to the time of its continuance. Vide Mr. Eaſon's caſes, Dr. Cormick, and others.

MEDIC. TRANSACT. &c.

conſtitution muſt be corrected and ſtrengthened before any relief can be had from Electricity: but this will require a little further explanation. If a perſon in this ſituation has recourſe to Electricity, no immediate effects will follow; it will not happen as in the former caſe, that a few ſhocks at a particular period ſhall produce the diſcharge. There muſt be firſt of all a conſtitutional amendment; ſteel medicines will here be ſerviceable, if the ſtomach can bear them, and ſlight ſhocks of Electricity, by gently ſtimulating the uterus to action, will coincide with this treatment; but they ſhould be ſlight, for the difference between theſe varieties is this: in the former caſe we were to aſſiſt the diſcharge of that fluid which was already prepared; in this we are to aſſiſt nature to prepare it: the one promotes the action of the uterus which was deficient, the other alters the action which is improper. Hence the impropriety of a practice not unfrequently had recourſe to, giving deobſtruent or forcing remedies previous to thoſe which are calculated to prepare the body for that change which is neceſſary for its perfect health and proper preſervation.

We ſhould unneceſſarily prolong this eſſay to enumerate caſes of menſtrual obſtruction cured by Electricity. So much has been already known and written in ſupport of its efficacy; it therefore became more uſeful to deliver ſome remarks on the nature and peculiarities of thoſe complaints, as far as regarded the adminiſtration of Electricity. I am perſuaded, from repeated inſtances and continued obſervation, that it moſt of all deſerves the name of ſpecific for theſe caſes, and that it ſcarcely ever fails if properly applied and regularly continued. It will only be neceſſary, before we conclude our obſervations on this ſubject, to apprize perſons of the caution which is neceſſary to be attended to in caſes where there is reaſon to ſuſpect pregnancy may exiſt. The ſlighteſt ſhocks here will be improper and dangerous, and more powerful ones certainly prejudicial. Another remark of a different nature may prove intereſting, though when conception has taken place, Electricity will be improper; it may be uſed with advantage with a view of favouring that proceſs. There is no doubt but that the ſtimulus of Electricity is well calculated to relieve ſterility in women, as it does impotence in men. We know the ſeat of conception is in the ovarium, which if it is not ſuſceptible of the ſtimulus of impregnation, the woman muſt continue barren. There are frequent inſtances of perſons being married ſeveral years without children, who have afterwards borne them, from an alteration taking place in the diſpoſition of thoſe parts. Hence Electricity will produce an alteration favourable to this * proceſs.

In the former part of this eſſay we made ſome remarks on that ſpecies of Paralyſis, which is more connected with and dependent on the ſtate of the brain, and where the effect was rather general in the ſyſtem. There are however ſeveral other kinds or degrees of paralyſis which are benefitted by Electricity, different from thoſe we have hitherto conſidered, varying in the locality as well as the cauſe of its exiſtence. Such are partial interruptions to the diſcharge of particular functions, as a paralyſis of the bladder depriving it of the capability of evacuating its contents, a paralyſis of the veſiculæ ſeminales occaſioning a want of retentive power. Theſe may with ſome propriety be deno-

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* It will require further opportunities to aſcertain to what extent Electricity can be beneficially employed, with this view. There can be no doubt of its being capable of producing that change and ſuſceptibility in the parts we mentioned: this is plain from analogy. Experiments have been made on Ova of different animals, and it has been found that thoſe which were electrified were hatched ſooner than thoſe which were not. But the ſame experiment ſhewed the neceſſity of regulating the power of this principle, for ſtrong ſhocks deſtroyed the poſſibility of their being hatched altogether.

Vid. Dr. Kæstlin's Experiments,
& Dr. Bohadsch's Experiments.

minated local paralyſis. The palſy, which attacks perſons who work in lead, is likewiſe different in the cauſe of its violence, from other ſpecies of paralyſis; we ſhall take notice of theſe, as we are furniſhed with facts to prove the uſe of the remedy we recommend, and firſt of

PARALYSIS OF THE BLADDER.

An elderly gentleman (near ſeventy) had ſo far loſt the power of diſcharging his urine, as to be obliged to receive temporary relief from the introduction of a catheter. This was an unpleaſant, though an unavoidable alternative; for beſides the pain it gave him at the time, the parts became more ſuſceptible of it from its repetition: he therefore readily conſented to the trial of Electricity. A few ſhocks were ſent through the pelvis, Electrometer one-eighth of an inch: from this no ſenſible benefit was immediately obtained. The next day the ſame operation was repeated, and continued every day under the ſame circumſtances for a fortnight. No change was even yet perceptible. What was to be done? would it have been proper at the end of this time to have neglected the uſe of Electricity, from a perſuaſion of its being

ing uſeleſs? No. A further trial was agreed on, and a more powerful ſtimulus applied, for a fortnight longer, with evident advantage, for he could void about a tea-ſpoonful of urine: by degrees he diſcharged more, and at the expiration of between five and ſix weeks, the patient had no further uſe for the catheter, as he was quite recovered.

This caſe will in ſome meaſure tend to overturn an opinion which ſome entertain, that where Electricity is ſerviceable, it produces its effects ſpeedily. This ſuppoſition is very dangerous in its tendency, as it leads a patient to diſcontinue that which would ultimately be productive of the happieſt effects. It is the more important to oppoſe this ſentiment, becauſe Electricity is often recommended as the derniere reſort, and little relief is expected in many caſes where this has failed. I will venture to avow this truth, that I have known perſons who laboured under hemiplegia not very ſevere, and who under the chronic ſtate of it have uſed Electricity, diſcontinue its uſe in leſs than a week, becauſe they were not ſenſibly benefitted; as if they were to be cured by ſome magic touch, or ſome celeſtial fire. Whilſt others, who have been in every reſpect worſe, have been cured by the ſame treatment, adminiſtered with greater continuance. If there are any diſorders wherein we ſhould make an exception to this remark, it muſt be ſpaſmodic diſeaſes: in theſe indeed we have inſtances of perſons cured inſtantaneouſly. But even in theſe affections, to complete the cure and obviate a return, it is neceſſary it ſhould be repeated for ſeveral times, as it will alter the diſpoſition of the parts to take on that action.

We ſhall now relate a caſe wherein Electricity has proved remarkably ſucceſsful, and in this peculiar affection very little has been ſaid in favor of Electricity; I mean

PARALYSIS of the VESICULÆ SEMINALES.

MR. Bell, I believe, has the ſole merit of diſcovering that the evacuation of ſemen, which takes place under improper circumſtances, depends on a paralytic affection of thoſe parts. The propriety of the opinion ſeems juſtified by the reſult. He himſelf ſays, I have found Electricity ſerviceable in thoſe complaints; and it was from his recommendation I applied it in the following caſe.

A gentleman in the army, about five and twenty years of age, in very good health, and apparently free from any other morbid affection, ſuffered conſiderable inconvenience from an inability to contain his ſemen; nocturnal emiſſions were very frequent: indeed every morning about ſix o'clock he experienced this effect, and what was ſtill more diſtreſſing, even in the day-time, the ſlighteſt ſtimulus of mind or body brought on a return. This was an embarraſſment from which it will eaſily be ſuppoſed he was ſolicitous to be relieved. It deſtroyed the happineſs of his life, by laying an embargo on his conduct, for even the ſlighteſt female familiarity was ſufficient to excite his paſſions and produce the ſymptom we have deſcribed. He came to us to be electrified, agreeable to the advice of Mr. Bell, of Edinburgh. At firſt ſparks were adminiſtered along the perinæum; theſe produced no alteration, though frequently repeated: a few ſlight ſhocks were then adminiſtered, one director being applied to the perinæum and another to the pelvis. The very firſt application was attended with advantage, for the following morning no emiſſion took place, which had not been the caſe for ſeveral years before. The ſhocks were daily repeated for about a fortnight, and the patient cured.

As this is a caſe not generally obſerved, at leaſt not generally treated as above, we ſhall take the liberty of making a remark on its nature and cure. An evacuation of fluid, from the vericulæ ſeminales, it is true, very often occurs in different men; but the more uſual cauſe of its being brought on, is preſſure from hardened retained fœces.

When it is produced on this occaſion alone, it is not of conſiderable conſequence; we can account for it mechanically; though here the function of the part is imperfect, the part is weaker than natural; but then it cannot be conſidered a morbid ſtate of debility, if it does not continue when that cauſe is not applied, there ought to be a decided diſtinction between the different ſpecies of this affection; for there is a difference in the ſtate of the part, in the ſtate of the conſtitution, in the effect of the diſeaſe, and in the nature of the remedy. The difference in the ſtate of the part conſiſts in its being paralytic, without any diſeaſed irritability; or paralytic, with morbid irritability. This may appear inconſiſtent, but will, it is hoped, be eaſily explained and underſtood, by recollecting that there may be a want of tone in the veſiculæ ſeminales, and yet an exceſs of irritability in the muſcles, the levatores ani, and muſculi tranſverſales, and the acceleratores, which are all concerned in the evacuation or natural propulſion of the ſemen. Hence a ſtimulus of a ſlight degree, an excitement much inferior to what is natural, will throw theſe parts into action, and propel the contents of the veſiculæ ſeminales. This is eaſily diſtinguiſhed from the other kind, for here there are evident ſymptoms of local, and generally, of conſtitutional irritability. This deſcription is always accompanied with an erection of the penis, and comes on at other ſeaſons than when going to ſtool. The diſcharge is occaſioned in this inſtance by an *action* of the parts themſelves, in the other by the *contents* of parts adjacent; in the one inſtance it may be conſidered an active, in the other a paſſive affection. Theſe are ſufficient to ſtamp a difference between the one and the other: the ſame principle conſtitutes the difference in the conſtitution, one being morbidly excitable, the other not. There is a practical inference annexed to this diſtinction, as medicines which allay irritation would be adapted to one, thoſe which had a tendency to open the body would be peculiarly appropriated to the other: the reaſons have already been aſſigned. Yet Electricity will with conſiſtency be applicable to both, inaſmuch as it would aſſiſt the retentive power in both, without increaſing the irritation in either; but with reſpect to the difference in effect, it is material and evident. A perſon who only ſuffers occaſional inconvenience from coſtiveneſs, will be enabled to exerciſe the functions of the parts at other times with freedom and effect: he is not at all diſabled from propagating his ſpecies, but the almoſt continual excitement of the other, prevents the ſemen from being prolific, and occaſions a ſpecies of impotence. The violence or exceſs of this latter affection, will be beſt aſcertained by this circumſtance, that when in a ſlight degree the erection of the penis will be complete, when in a more obſtinate degree it will only be partial. In the treatment of this affection it will be proper to recollect that venereal intercourſe need not be forbidden, indeed it becomes favourable to the cure; for if a patient has been accuſtomed for ſome time to a daily diſcharge, the parts will not be enabled to retain their contents * for ſuch a length of time, or bear ſuch a degree of diſtention as another: therefore till it has had time to recover its functions effectually, moderate venereal indulgence will be attended with no bad effect.

We ſhall now proceed to the conſideration of ſome diſeaſes attacking parts in the vicinity of thoſe juſt mentioned.

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* This hint with reſpect to the difficulty of altering any long eſtabliſhed habit, is particularly illuſtrated by diſeaſes of the bladder, and ſhould be attended to; for when a perſon has a particular irritation in that part, he feels diſpoſed to evacuate the urine, even when in a ſmall quantity. The conſequence of which is, that it becomes incapable of diſtention, even when the original cauſe of the irritation is removed, and therefore the patient ſhould not encourage every ſlight propenſity to diſcharge his urine, for I have known inſtances of perſons thus inducing a kind of artificial irritability.

ENLARGEMENT OF THE TESTES.

The enlargement of one or both of the Teſticles not only proceeds in different caſes from different cauſes, but is likewiſe different in its appearance, as well as in its termination, and therefore requiring a different treatment, demands ſome rule for diſcrimination. When from the uſe of any ſtimulating injection, or from the violence of gonorrhœal inflammation, a ſwelling attended with pain takes place in the Teſticle (an effect very common), it is denominated Hernia Humoralis; in proportion to the violence of their ſymptoms, ſuch will be the diſtention of the Tunica Albuginea, and ſuch the ſize of the ſwelling: now as the Tunica Albuginea is an elaſtic ſubſtance, the enlargement will continue after the cauſe is removed; for we are to expect no contractile power from theſe parts. The part under theſe circumſtances may be conſidered as in a chronic ſtate, and here Electricity may be advantageouſly employed. Again, when any ſlight blow has been received on thoſe parts, *that* will be ſufficient in ſome conſtitutions to occaſion an enlargement; and *here* Electricity may be uſefully employed, after the firſt ſymptoms of excitement have been leſſened. (We are only curſorily mentioning the different varieties; we ſhall hereafter relate caſes which have occurred to illuſtrate each). But when the Teſticle not only becomes enlarged, but is at the ſame time remarkably hard, feeling almoſt like a ſtone, and being conſiderably heavy in proportion to its bulk, and more eſpecially if to theſe ſymptoms the patient feels at times violent lancing, ſhooting pains, and what is particularly characteriſtic of danger, has a knotted feel along the ſpermatic cord, Electricity will be improper and dangerous; for there can be no analogy between theſe laſt mentioned, and thoſe which immediately preceded in the hard firm ſwelling: every excitement ſhould be avoided. The part, if altered by any ſtimulus, if ſtimulated to any action, will be more likely to aſſume a cancerous action than any other. The principal palliative it requires, is reſt, and if this does not prevent its encreaſe, it can only be cured by extirpation; but in the other caſes to which we allude, there is not that tendency or capability of morbid action, there is an enlargement without pain; we may therefore apply a ſtimulus without danger. Inſtead of an excitement going on, or likely to do ſo, which may prove injurious, there is a want of excitement, which if ſupplied, will prove beneficial. To prove therefore the utility of Electricity in theſe complaints, we ſhall appeal to facts; but firſt of all take the liberty of premiſing ſome obſervations with regard to the proper mode of adminiſtrating this remedy, which to the young Electrician at leaſt will be found acceptable. In thoſe Tumors, beſides the increaſe of ſize in the Teſticle itſelf, there is generally a depoſition of fluid. The form in which Electricity is to be applied, is that of ſhocks, but this even will prove inſufficient, if not judiciouſly adminiſtered; for if they are only ſent through the fluid which is contained, and not through the Tumor, it can have no tendency to diminiſh its bulk. To avoid this, the directors muſt be preſſed rather firmly, ſo as to bring the ſcrotum into contact with the Teſticle; they muſt not be brought too near to each other, leſt the diſcharge ſhould paſs over, and not through the ſwelling. And it will be further neceſſary to paſs ſhocks of a conſiderable ſtrength to obtain the ſame effect, and on account of the inactivity of the parts, this degree of ſtrength will be eaſily borne; but though in thoſe parts it can be directed with advantage, it will be right to avoid paſſing ſhocks of the ſame ſtrength through parts which are not diſeaſed. As for inſtance, if there is only one Teſticle injured or enlarged, the other Teſticle ſhould not be in the line with the director, as it will give much immediate pain, and may be productive of future danger. It will be neceſſary, therefore, before this operation is begun, to feel for the ſound Teſticle; for in conſequence of the varied action of the cremaſter muſcle, it is ſometimes at the upper, ſometimes at the inferior part of the ſcrotum. The directors ſhould be changed conſtantly, or ulceration, as we have before remarked, will be produced; beſides theſe particulars, it muſt be remembered that ſometimes the ſenſibility of the ſkin is ſuch, as not to allow of that requiſite ſtrength in the ſhock which is abſolutely neceſſary to accompliſh the diminution in ſize. How are we to relieve this inconvenience? A very eaſy expedient will ſuffice. Let ſparks be applied to the whole ſurface of the ſcrotum, ſo as to occaſion a general redneſs; and after having done this, ſhocks of conſiderable intenſity will be eaſily borne. In applying ſparks, it will be neceſſary to cover the part with flannel, or the points of the pairs which cover this portion of the ſkin, will draw off the electric fluid; but it muſt be laid aſide when the ſhocks are applied, as they will by the medium of the flannel be diſperſed upon the ſkin, and occaſion conſiderable pain there, inſtead of paſſing immediately through the ſubſtance of the Tumo

CASE I.

A gentleman of a ſound conſtitution, and about the middle period of life, violently bruiſed the right Teſticle, by preſſure on the ſaddle, when hunting. The inflammation which enſued, continued for nine or ten days, notwithſtanding the perſevering uſe of the moſt judicious means, and the Teſticle was conſequently much enlarged. It was a month after the time of the accident that Electricity was begun: every degree of pain and irritation had for ſome time previous to this been removed; and he had, during the laſt fortnight, rubbed ſome mercurial ointment on the ſcrotum every night without effect. Electricity was begun with, firſt by paſſing twenty ſhocks of a moderate ſtrength through the Teſticle. They were repeated every day, and gradually increaſed in ſtrength, that the effect might not be leſſened by the part being accuſtomed to the ſtimulus: a perceptible decreaſe of ſize took place in a fortnight, and in a month the enlargement was entirely reduced.

Though there is nothing remarkable in the progreſs of this caſe, it ſhews ſufficiently the powerful influence of Electricity in theſe affections; but it is adduced alſo to ſhew the difference between this and another derangement of the ſame parts, which bears ſome reſemblance to its cauſe, appearance, and ſometimes in its termination; I mean that kind where, together with the enlargement and diſtention of the natural parts, there is likewiſe a depoſition of a watery fluid. Though the ſame remedy is applicable here, it is not ſo ſpeedy or certain; and this muſt neceſſarily depend on the quantity of water *effuſed*, and the ſtate of the parts *effuſing* it. Hence a very obvious difference in theſe two diſeaſes. In the firſt inſtance where violent inflammation occaſions enlargement and diſtention, it is not the effect of morbid action, only the natural action is increaſed; pain, ſwelling, and other ſymptoms follow; and among other conſequences, there is a depoſition of coagulable lymph. When this deviation from the natural excitement of the parts has ceaſed, they will then be capable of removing the ſuperfluous matter which is depoſited. But this is not without the aid of other means: the abſorbents of the parts require ſome aſſiſtance, and the uſe of Electricity enables them to accompliſh that which, without its influence, it would be incapable of doing. Beſides this, it is probable Electricity acts by rendering the fluid more fit to be taken up by the ſyſtem of veſſels. Hence in Ganglions, which have remained ſtationary for years; a blow upon

them,

them, by diſturbing the texture or arrangement in their ſubſtance, occaſions them to be abſorbed. That Electricity has a ſimilar operation, is likewiſe probable from the effect of lightning.

A woman who had a ſchirrous Tumor in her breaſt for ſome years, was ſtruck by lightning juſt in that part; the ſhock was neceſſarily ſevere, but in three days the Tumor diſappeared. With regard to the other ſpecies we have endeavoured to deſcribe, there is a difference in the nature of the fluid, as well as the ſtate of the parts. This will ſerve as a comment on the difference I have ſtated to exiſt between *morbid* action and *increaſed* action; the fluid under *increaſed* action is more readily abſorbed, whereas the other is not; and why? becauſe there is not that ſame capability of its doing ſo. There muſt have been ſome alteration in theſe parts, or in their functions, to have produced this fluid, or to have left it remain after it was produced; and this alteration conſtitutes a difference in *the ſtate of the parts*. That there is a difference in the nature of the fluid, is likewiſe evident; it may be remarked that coagulable lymph, or that fluid which is effuſed under a healthy inflammation, is more adapted to the proceſs of abſorption than any other. In every injury nature pours out this fluid to ſtop the danger, or ſupply the deficiency;

ency; and whatever is ſuperfluous to her intentions ſhe removes. But to proceed to the caſe which will illuſtrate theſe remarks.

CASE II.

A gentleman about thirty years of age, applied to me on account of a diſeaſe of the Teſticle, with which he had been afflicted ſome months. His hiſtory of the caſe was nearly as follows: about ſix months ago he obſerved an enlargement on the left Teſticle, which he thinks came on without any blow or injury being received. He left it for ſome weeks without applying any remedy or ſeeking any advice; it very gradually increaſed in ſize, and he conſulted a ſurgeon about it, from whom he took Cicuta and Calomel, and rubbed Unq. Merc. on the part: this plan he regularly perſevered in for a conſiderable time, yet without effect. He applied to me, in order to try Electricity, and at this time the ſtate of the parts was worſe than before. On examination I found the Teſticle itſelf enlarged, but not hard, rather ſofter than natural: this increaſe of ſize however did not form the whole bulk of the Tumor, for there was a very evident collection of fluid, and therefore the chances of ſucceſs were leſs; for beſides the time which would be required to remove this depoſit, there did not appear to be power in the parts to accompliſh it; however, as the ſpermatic cord was perfectly ſound, and no pain in the Teſticle which could indicate danger, Electricity was tried. I begun by firſt applying powerful ſparks to the whole ſurface of the ſcrotum, by which I was enabled to ſend ſhocks thro' the Tumor without occaſioning much pain. The ſhocks were daily increaſed in number, and continued with much regularity for the ſpace of a month or five weeks, with only this apparent utility, that the Tumor was not in the leaſt increaſed: it was continued about three weeks longer, when unfortunately the gentleman was obliged to leave town on ſome important buſineſs. The ſize was now certainly leſs, and from further perſeverance it is probable he might have been cured.

The event of theſe caſes is by no means uniform; where there is a large collection of fluid, it is beſt to evacuate it by making an opening with a trocar, and afterwards electrifying it, adheſion will follow. In this manner it may be very advantageouſly employed in Hydrocele, making a conſtant preſſure upon the part after the water is diſcharged, and electrifying it with as much power as the patient is capable of bearing.

RHEUMATISM.

It will ſcarcely be neceſſary to inform the reader that there are two ſpecies of this complaint remarkably different from each other in their ſymptoms, peculiarities, and treatment; theſe are denominated the *acute* and *chronic*. It is to the latter we ſhall principally confine our obſervations, as it is in this Electricity is more eſſentially ſerviceable. However undetermined the queſtion may be with regard to the effect of Electricity in quickening the pulſe, or accelerating the ſecretions, when the patient is only charged with this fluid by inculation, no doubt can be entertained of its power when communicated by ſhocks. We may preſume on this principle to account for its effects, from conſidering the circumſtances by which the complaint is occaſioned: it is moſt frequently brought on by expoſure to cold, when the patient is warm and the ſkin moiſt; a ſudden ſuppreſſion or obſtruction to the perſpirable matter, then, may be allowed in the firſt inſtance to be the ſource of the affliction: hence the variable and fluctuating ſtate of the patient's feelings, ſubjecting him to the influence of every viciſſitude of ſeaſon or climate, and rendering him almoſt a walking barometer. But whatever may be the proximate cauſe of the diſeaſe, or the modus operandi of the remedy, its advantages are too obvious to be denied; at leaſt the following caſes will prove the fact.

CASE I.

A gentleman who is not much accuſtomed to travelling, was ſeized with violent rheumatic pains, in conſequence, he ſuppoſes, of being obliged to ride in a very rainy day from London to Windſor; the pain was ſo ſevere as to confine him for ſeveral days to his bed By the uſe of the remedies adminiſtered to him, the urgency of his ſymptoms ſoon began to abate, but he was ſtill afflicted with pain in the ſmall of the back, extending along up to the ſhoulder; theſe ſymptoms increaſed as the ſeaſon advanced, for it was about the latter end of autumn. He continued to labor under the complaint with more or leſs violence throughout the winter, notwithſtanding the uſe of liniments, plaiſters, ſudorifics, and every thing which could be recommended. About a twelvemonth from the commencement of the diſeaſe, he begun the uſe of Electricity: his pain was now fixed in the loins; he was not much relieved in the firſt week, when only ſlight ſhocks were ſent through the part, but by increaſing their ſtrength, he ſoon perceived their efficacy. He continued the uſe of the Electricity for nine weeks, when he felt himſelf perfectly cured, and by obſerving more caution in cloathing and going out, felt no return during the winter.

CASE II.

A lady, by ſitting in the direction of a current of air, was incapable of moving her neck without the moſt violent pain; ſhe was cured in a few days by the application of powerful ſparks to the neck.

Theſe and a variety of ſimilar caſes might be recorded, but would be of leſs conſequence to mention, as they are well known to ſubmit to this remedy. It will therefore be ſufficient to cloſe theſe preceding pages, by ſome general obſervations on the application of this fluid in a few other diſeaſes not yet alluded to, in

GOUT.

In the early ſtages of this diſeaſe we have ſeldom reaſon to expect any ſerious conſequences, and therefore it will be uſeleſs, as well as miſapplied, to add any remarks on the treatment beſt adapted to this ſtage of the diſeaſe. It might indeed be an object worthy inveſtigation, what cauſes prediſpoſe certain conſtitutions to the gout more than others, and what means will be likely to obviate or correct this diſpoſition; but this does not come under the deſign of the preſent pamphlet. The circumſtances to which Electricity is adapted, are principally of two deſcriptions; the one, where Gout having frequently attacked the extremities, at laſt endangers the vital organs; the other, where inſtead of being determined to one particular part of the body, it flies from one ſituation to another, conſtituting the irregular or miſplaced Gout.

In the former of theſe its effects are ſuperior, for by its powerful ſtimulus it will more ſpeedily accompliſh that revulſion and determination from the ſtomach to the extremities, than other remedies which are employed. The more powerful machines will be neceſſary in theſe caſes, that ſparks of ſufficient ſtrength may be adminiſtered; it has ſeveral advantages, which in the ſituation in which ſuch patients are, will be found conſiderable, for it does not require that they ſhould undergo the fatigue attendant on moving them to a hot bath, or a pediluvium; it does not even become neceſſary to remove the flannels from the part, for if the machine is capable of giving ſuch ſparks as are neceſſary, they will act through an intermediate ſubſtance of that deſcription. Hence in relieving a gouty attack on any vital organ, whether the ſtomach, the brain, or any other viſcus, this remedy deſerves a preference.

In the irregular attacks of Gout, it will be found to relieve the patient from conſiderable ſuffering, and ſhorten the period of his indiſpoſition: its influence in this reſpect may be illuſtrated by analogy, e. g. when a perſon on expoſure to cold has an inflammation of the tonſils, which inflammation becomes conſiderable, and perhaps terminates in ſuppuration, he is much more liable, on being expoſed to ſimilar cauſes, to ſuffer an attack on thoſe parts than any other, becauſe they are more ſuſceptible than any other of the inflammatory action. With regard to Gout then; when a perſon labours under ſymptoms of irregular Gout, the pain ſhifting from one part to another, without being more confined to either in particular, let a few ſlight ſhocks be paſſed through the extremities, together with ſome ſtrong ſparks, and repeat this treatment every day, and the diſeaſe will be determined by this means to that ſituation. If it ſhould be aſked what benefit is thus obtained; it will only be neceſſary to reply, that by this treatment the patient is guarded againſt an effect to which he was before ſubject. For this ſpecies or peculiarity of the diſeaſe frequently diſpoſes it to attack the head, occaſioning giddineſs, pain, and ſometimes apoplexy. By fixing it to the extremities, this danger is removed. Another advantage is this: under the former ſymptoms, the patient is conſtantly haraſſed by the diſeaſe, but by bringing it into the form of a regular paroxyſm, he enjoys intervals of health and pleaſure, and may by proper treatment and prudent caution, ſometimes prevent a relapſe, or at leaſt prolong his relief.

I could adduce ſome caſes in proof of theſe remarks, were I not obliged to curtail the ſize of this pamphlet, and therefore I proceed to the conſideration of

DROPSY.

It has been a queſtion which ſtill remains perhaps undetermined, whether this diſeaſe ariſes from an increaſed ſecretion, or a diminiſhed abſorption. That in many inſtances it originates from the former, will not be difficult to demonſtrate, and it will then be eaſily underſtood how the adminiſtration of Electricity can prove beneficial, e. g. one frequent, if not the moſt uſual cauſe of Dropſy (Aſcites more particularly) is an obſtruction to the paſſage of the blood through that organ; conſequently there muſt be a proportional determination of fluids to ſome other parts. In theſe caſes, ſhocks ſent through the liver will be found highly ſerviceable; that is to ſay, when there are no ſymptoms of active exiſting inflammation, it may be very uſefully combined with mercury, when given with a view of curing a chronic affection of that viſcus, and will be found to agree beſt under the ſame circumſtances in which the uſe of that medicine is found proper; it will tend to quicken the circulation through it, and to remove thoſe ſchirrous affections which are the cauſe of the diſeaſe. But there is another part of the animal œconomy peculiarly deſtined to the ſecretion of the watery part of the blood. This is the kidney in which obſtructions frequently happen, and prevent the natural outlet to the paſſage of the fluids. In theſe caſes Electricity has been found the moſt powerful diuretic in every conſtitution diſpoſed to Dropſy; it becomes abſolutely neceſſary to render the paſſage through the kidneys perfectly free, as there being already a tendency for the watery parts of the blood to run into ſome other channel, that will be greatly accelerated if the kidneys are not capable of exerciſing their natural functions. There is in many inſtances a degree of torpor and inactivity in theſe organs, rendering them unfit for their office; and hence it has often happened that by the paſſage of ſhocks through them, a patient has very ſhortly afterwards evacuated a large quantity of urine. The ſame precaution is neceſſary to be obſerved here, however, as in other inſtances, not to apply it under a ſtate of inflammation.

NERVOUS HEAD-ACH.

This is a complaint in which Electricity, under certain circumſtances, will be found beneficial. I do not mean to aſſert that it is capable in every inſtance of Head-Ach occurring in delicate irritable habits, of giving that firmneſs to the nerves as to prevent their being affected by the ſame cauſes, but that it will in thoſe caſes prove ſerviceable where there is a fixed pain, or rather a pain in one particular fixed part, forming what is called the Clavis Hyſtericus. Every one almoſt muſt be acquainted with this deſcription of Head-Ach, and muſt likewiſe know how inadequate medicines frequently are in preventing their return: in fact, after a certain continuance, the part being in the habit of ſuffering this attack, it returns at length at regular ſtated intervals; and ſo great is the diſpoſition to relapſe, that the moſt powerful means will not prevent it; and opium, which at other times will affect the patient very ſenſibly, will have no effect at all in diminiſhing the pain. In theſe caſes it is neceſſary to paſs ſhocks through the head, at the part where this pain is ſeated: this treatment ſhould be begun about a week previous to the period at which it is expected to return, and continued till about the ſame time has elapſed beyond that time. This does not preclude the neceſſity of other means directed for this complaint, among which cold-bathing, air and exerciſe, and abſtaining from the uſe of the ſtrong fine teas, are very important.

METALLIC TRACTORS;

OR, THE
EFFECTS OF COMBINED METALS
ON THE
HUMAN BODY.

WHEN the peculiar properties of the Gymnotus, Torpedo and Silurus were aſcertained to be of an electric nature, that theſe had been wonderfully provided with organs calculated for the accumulation and evolution of this ſurpriſing principle, in order to arreſt their prey, then many philoſophers began to attribute to Electricity a variety of other phenomena. The moſt remarkable is that communicated in a letter from Dr. Cotugno to Chevalier Vivenzio in 1784, reſpecting a mouſe being an electrical animal; caſually holding the ſkin of the back between his finger and thumb, in order to make an inciſion into the abdomen with his pen-knife, the tail of the mouſe was ſecured between the two laſt fingers; in the ſtruggle of the animal, the tail vibrated, and he felt a ſhock through his left arm up to his neck, attended with a giddineſs of the head, which continued a quarter of an hour.

Although this ſame operation has been repeated many times by others, no ſuch effects have ever been experienced; and from one ſolitary inſtance no fair deductions can be made.

Seven years after this period, Galvani publiſhed his curious experiments; in theſe he has ſhewn that a frog, dead and ſkinned, is capable of having its muſcles brought into action by means of artificial or atmoſpherical Electricity; and ſecondly, has diſcovered, that independent of any artificial or natural Electricity, the ſame motions may be produced in the dead animal, or even in the detached limb, by making a communication between the nerves and the muſcles with ſubſtances that are conductors of Electricity. On this account it is that the name of *Animal Electricity* has been beſtowed on this wonderful property.

In the beginning, when the muſcular power is ſtrong, the inſtant after the head of the frog is removed, the muſcles will be thrown into convulſive actions by the ſlighteſt diſturbance. Pieces of the ſame metal, even the mere agitation of the table will ſuffice: afterwards different metals are required; the more diſſimilar the metals, the better the effect; as gold and lead, ſilver and zinc, are better than gold and ſilver, or lead and zinc.

This property is not peculiarly confined to the frogs, the muſcles of every animal are ſubject to the ſame agitation; as the muſcular parts of the more imperfect animals retain longer the principle of life, they are longer liable to this influence. Thus alſo we find the living body ſenſible of the action of metallic applications. If we place a piece of zinc under the tongue, and a ſhilling between the upper lip and the gum, and when theſe are diſengaged from the finger, and brought into contact by elevating the under jaw, not only a remarkably pungent taſte is experienced, but alſo a flaſh of light before the eyes.

If a ſlip of tin foil be placed upon the eye ſhut, and a ſilver ſpoon in the mouth, on completing the communications between theſe metals, a white light will appear.

Some perſons experience different ſenſations; in ſome the ſenſation is hardly perceptible, in others it is very ſtrong. Volta ſays he perceived ſomething of an alkaline nature when the ſilver is applied to the apex, and the tin to the back part of the tongue; when theſe metals were reverſed, the taſte was ſubacid. Dr. Monro, when trying it between the upper lip and the tongue, always felt a pain in the upper jaw; and when he applied a probe of zinc to the inſide of the noſe, and a piece of ſilver to the tongue, ſeveral drops of blood fell from the noſtrils; Dr. Fowler experienced a ſimilar effect.

Mr. Robinſon obſerves, that if a Rouleau is made of pieces of zinc and ſhillings, when in the mouth the irritation is very ſtrong and diſagreeable. Thus we may diſcover the ſtrong taſte of ſoldered ſeams of metal in braſs and copper veſſels, which the eye cannot perceive.

Theſe circumſtances prove that metals poſſeſs different degrees of Electricity, yet their difference is ſo ſmall that they cannot overcome the reſiſtances of the air, &c. ſo as to equalize themſelves. When in contact with ſubſtances which are better conductors, then an evolution will take place from that which poſſeſſes the exceſs.

So trivial is the quantity of Electricity diſengaged, that the moſt delicate Electroſcopes are no ways ſenſible to it; even to influence the muſcular fibre, immediate contact is requiſite; if even the cuticle is interpoſed, the whole effect is deſtroyed.

Notwithſtanding this, a Dr. Perkins, of an American Province, has ſolemnly avowed to the world, that by means of metallic combinations, formed into kind of pencils, by drawing theſe gently over any part of the body labouring under any fixed pain, that the pains have been removed.

Dr. Perkins ſeems to ſuppoſe that in the human frame, there may be local exceſſes of Electricity; ſuch an hypotheſis requires many proofs to its ſupport. Even allowing this, the metals thus combined poſſeſs no power of equalization, they produce no alteration in the ſtate of Electricity in the animal frame; the whole change which is induced, is between themſelves.

Metals, as already obſerved, applied to the ſkin, have no influence: if then the gentle irritation of theſe tractors is any ways beneficial, muſt either be by acting on the imagination of the patient, or by the pleaſing mechanical ſtimulus. Dr. Thornton aſſured a medical ſociety in town, by the requeſt of Dr. Perkins he tried the tractors on a poor woman who complained of pains in both arms; he applied the tractors to one arm; ſhe felt herſelf immediately relieved. To aſcertain whether the relief was dependent on this, he drew a wooden ſkewer over the other arm; the woman experienced ſimilar relief; which demonſtrates that it no ways depended on any peculiar properties of the tractors.

I have tried them frequently on thoſe whoſe minds were not to be eaſily worked upon and have never perceived the leaſt effect. I prepared tractors of tin, zinc, copper, and braſs, in every different proportion; have never found this to produce any other effects than what might be procured by a common nail.

FINIS.

AN ANALYSIS OF A *COURSE of LECTURES* ON THE PRINCIPLES OF NATURAL PHILOSOPHY,

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AN ANALYSIS ON THE *PRINCIPLES* OF NATURAL PHILOSOPHY.

MATTER.

MATTER, as derived from *Mater*, the mother, in the abſtract implies a more confuſed and general idea of ſolidity, with little or no regard to figure, proportion, or quantity; the form under which Matter appears, is generally termed *body*, and that which ſupports or ſtands under the different forms which are preſented to our ſenſes, is characteriſed by the word *ſubſtance*.

Matter exiſts wherever there is a RESISTANCE. Figure and extenſion are ſuperfluous in the definition.

Matter in its primary ſtate is homogeneal, by the different combinations of theſe primary particles produce a proportionate variety in the conſtituent particles, which by their arrangement form the different claſſes of natural bodies that compoſe this earth.

Thus it may be ſuppoſed that two primary particles united, may form a conſtituent particle of light; three particles united, a conſtituent particle of fire; four, a conſtituent particle of air: and thus by different combinations, form that great variety of bodies we ſee.

To theſe conſtituent particles our chemical powers are limited; a conſtituent particle of mercury can no ways be changed into a conſtituent particle of gold. The powers of life can reduce theſe conſtituent particles, and by different combinations produce different reſults.

Had the globe been placed in any other part of the univerſe, the nature of bodies muſt have been materially different. Under the influence of different cauſes, different combinations would have taken place: the principle of life diffuſed through the univerſe being rouſed to different actions, the combinatory products would have differed alſo.

The different ſtates in which Matter appears are three:

Firſt. A ſtate of fortuitous concourſe, where in its accumulation no ſpecific form has been aſſumed; no peculiarity of appearance defined.

Secondly. The arrangement by the power of life, to which the greateſt portion of natural bodies is reducible, as *wood*, *coral*, *ſhells* of all cruſtaceous animals, *marble*, *ſtones*, *ivory*, *metals*, *coal*, *ſulphur*, and probably every ſubſtance which has an uniformity in its appearance, without any cryſtaliſing arrangement, to this cauſe may be attributed.

By this power the female glow-worm forms her phoſphorus, the bee its honey, and the ſerpent its poiſon.

Thus fern leaves conſiſt of one quarter iron: this metal is not found peculiarly in the earth in which the fern vegetates, nor in the air which ſurrounds the plant. It muſt originate from ſome powers of combination inherent in the plant; the ſame powers which form the peculiar ſap, the ſame can convert the conſtituent particles of one body into thoſe of iron.

Thus ſhell-fiſh can convert their own nouriſhment into envelopements of aërated lime, and the coral formed into maſſes of an enormous extent by the united labours of myriads of polypes: from 2
theſe all ſpecies of calcareous earth derive their origin, as marble, ſtones, &c. In the Atlantic

Ocean and the Northern Seas are extenſive rocks of coral daily increaſing; theſe in the courſe of ages lay foundations to iſlands: we may thus conceive how Delos and Rhodes roſe out of the ſea, and the two iſlands of the Azores which emerged in the ſixteenth century.

As theſe combinations are the reſult of the agency of life, according as this principle is influenced, ſo the products will be alſo. Thus the debilitated ſtomach of the gouty patient, inſtead of performing its duty with its uſual energy, decompoſes the fluid with which it is ſupplied, and converts it into large quantities of air.

Thus animal ſubſtances under certain circumſtances, with reſpect to temperature, moiſture, and air; the balance of affinities is ſoon broke, and the putrefactive proceſs takes place.

When the ſame ſubſtances are placed in water, the ſame changes do not take place, the principle which in the one is evolved, is here retained, and the whole converted into a waxy ſubſtance.*

So

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* My friend Dr. Gibbes of Bath, well known for his accurate experiments on the converſion of the component parts of animal ſubſtances, into a kind of ſpermaceti, thus elegantly explains the change which fleſh undergoes in water.

" Fleſh

So vegetables, when preſſed by large maſſes of earth from the unequal action of earthquakes, or the overwhelming of volcanic powers; where whole foreſts are ſwept down and ingulphed by thoſe convulſions; the amazing ſuperincumbent preſſure, and the different change of ſituation, conſolidates and converts the vegetable ſubſtance into coal; and thus under a little change of circumſtances, may be converted into ſprings of Petroleum and rivers of Naptha.*

" Fleſh and animal matters in general, are compoſed of oxygene, hydrogene, carbone and azote; water is compoſed of oxygene and hydrogene, and the ſubſtances which are formed are fatty matter, or a triple combination of oxygene, hydrogene, and carbone; ammonia, in ſmall quantities, compoſed of hydrogene and azote; carbonated hydrogenous gas compoſed of hydrogene and carbone; and nitrous acid compoſed of oxygene and azote.

* Coal mines in the vicinity of volcanoes, there are ſprings of Petroleum and rivers of Naptha. At Baku there are ſtreams of Naptha in a continual ſtate of combuſtion.

Thus the vegetable fixed alkali is formed from the Lixivium of common wood aſhes, while the mineral alkali is obtained by the ſame proceſs from marine plants: ſituated on the Weſt of Delta, Sicard and Volney tell us of lakes of Natron found in a native ſtate.

Thus in the former caſe the vegetable forms an union of nitrogenous gas with lime to conſtitute pot aſh; while in the latter the gas unites with magneſia to form the ſoda.

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So ſulphur is formed by the decompoſition of vegetables and animals; and Monſieur Deyeux ſays it exiſts naturally in certain plants.

Third State of Matter is the arrangement by cryſtallization. In various minerals we obſerve a ſomething more than a mere fortuitous concourſe of the conſtituent particles; there is a ſymmetric aſſemblage, a beautiful arrangement, appropriate to particular bodies. When theſe preſent themſelves under any regular form, whoſe faces may be repreſented by geometrical figures, ſuch are called cryſtals.

This arrangement can only take place when the conſtituent particles are in a fluid ſtate, and running gradually into a ſolid form.*

It has been thought that this arrangement is effected by the influence of a power, a degree inferior to vegetable life.†

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* If we dip a thread into a ſolution of allum, we find the thread will be covered with little cryſtals of an octohedral form; if we again immerſe the thread, we do not find an accidental ſcattering of the ſame cryſtals in different parts of the thread. The ſucceſſive layers are determined to the firſt cryſtals, increaſing their ſize with the ſame octohedral form.

† Haller obſerves that animal life is a degree above vegetables, and vegetable life a degree above cryſtallization. Von Linnæus ſays, "Lapides creſcunt, vegetabilia creſcunt & vivunt;

Since Mr. Lichtenberg has ſhewn what beautiful configurations may be produced on an electrephorous, and the ramifications influenced by the ſtate of Electricity, with ſome degree of reaſon it has been thought that cryſtallization may be owing to the influence of the ſame principle.

As bodies have different capacities for Electricity, ſo the conſtituent particles of different minerals poſſeſs different degrees of power; if they are influenced in their arrangement by this power, each animal muſt have its own reſpective arrangement.

When the proceſs is ſlow, the arrangement is ſymmetrical and regular; when hurried, the ſurfaces are ill-formed, and ſometimes an aſſemblage of almoſt imperceptible moleculæ.*

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vivunt; animalia creſcunt, vivunt & ſentiunt." Monſieur Metherie and others have ſuppoſed that there are ſeeds of cryſtallization, that there is a ſpontaneous generation in the mineral kingdom; they have extended this doctrine ſo far as to ſuppoſe animals or vegetables are produced by the cryſtallization of the ſeed.

[*] Such is the difference between a rhomboidal calcareous ſpar, and a block of ſtalactites, or white marble; between a regular cryſtal of ſelenite, and the common gypſum or alabaſter; between a quartz or rock cryſtal, the hexagonal ſpecies with iſoſceles triangular planes, and the unformed quartz, as freeſtone, agate or flint.

When rendered fluid by heat, they are ſubject to the ſame influencing principle, and arrange themſelves in perfect order; inſtead of acting from a centre, they terminate here, and commence from the circumference.

This is the reaſon why the conſtituent particles of bodies rendered fluid by heat are more firmly united, than the arrangement of thoſe held in watery ſolutions.

In the cryſtallization of ſalts, each particle acts uncontrouled by any ſurrounding medium; not ſo with melted glaſs or metals; the ſurface is firſt cooled, and which neceſſarily prevents the expanſion of the interior portion, ſo that the conſtituent particles are gradually more and more wedged with each other.

Glaſs, when gradually cooled, is regular in its arrangement, if ſuddenly cooled or unannealed, break, however thick, with the ſlighteſt tremor.

Exp. with glaſs proofs.

Exp. Batavian, or Prince Rupert's Drops.*

On

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* Theſe Drops are known in England by the name of Hand-Crackers, of a pear-like form, with a long tail; when a ſmall part of the tail is broke off, the whole Drop is reduced into powder.

They are made by letting drops of melted glaſs fall into a veſſel of cold water; the tails are afterwards drawn out by means of a lamp.

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ON ATTRACTION AND REPULSION.

ALL the experiments which have been advanced in order to demonſtrate the exiſtence of certain active powers, may be reduced to the five following.

1. The tendency of light bodies floating on the ſurface of water contained in a veſſel, towards the ſide of the veſſel.

The glaſs is very rapidly cooled, and, as before obſerved, the conſtituent particles in a very imperfect ſtate of union; the interior portions of the Drop are ſlower in their cooling as they approach the centre, ſo that every ſucceſſive portion will have their conſtituent particles in a more perfect ſtate of union, and conſequently in a ſtate of greater approximation; as ſuch, every interior portion will recede from the exterior, forming involucra like the concentric partitions of an onion. All theſe ſpaces muſt be in the moſt perfect ſtate of exhauſtion, free from every particle of air.

That theſe intervals are in a ſtate of exhauſtion, may be farther proved, by rendering the Drops ſoft by heat; the bubbles diminiſh, from the glaſs, being compreſſed by the external air.

When a portion of the tail is broke off, a communication is formed between the atmoſphere and theſe concentric vacua; the air ruſhes in with violence into all the exhauſted intervals; each vitreous involucrum yielding to the tremulous impulſe, the conſtituent particles ſeparate, and the whole falls into ruins.

2. The riſe of fluids in capillary tubes.

3. The force with which two poliſhed leaden ſpheres cohere.

4. Reflection and inflexion of light.

5. Expanſion of bodies by heat, and contraction by cold.

Theſe are all reducible to pure mechanical principles, principles which are cognizable to every mind.*

The terms *powers*, *ætherial atmoſpheres*, *attractive* and *repulſive influences*, will be totally rejected as principles whoſe exiſtence we are unable to conceive, and which, inſtead of elucidating any phænomena of nature, involve them in ſtill greater obſcurity.

We ſhall hereafter ſee that in Electricity, Magnetiſm and Gravitation, that the adoption of ſuch terms is not only unneceſſary, but alſo unphiloſophical.

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* For the more particular examination of theſe experiments, the reader is referred to ſome phyſiological and philoſophical eſſays I lately publiſhed.

LECTURE II.

LAWS OF MOTION.

From the ſubjection of Matter to the influence of external agents, is deduced the firſt Law of Motion.

LAW I.

Every body perſeveres in its ſtate of reſt or uniform motion in a right line, until ſome external force acts upon it.*

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* The paſſive ſtate of bodies eaſily ſuggeſts to us the idea of its continuing in a ſtate of reſt, unleſs influenced by external powers: when impreſſed, the perpetuity of its motion is not ſo conceivable.

A man ſailing in a boat, or riding on horſeback, if the boat or horſe is ſuddenly ſtopped, he falls forwards.

The ancients had many quibbles about motion; Diodorus Siculus denying its exiſtence, and Zeno endeavouring to prove the ſame from the circumſtance of Achilles and the tortoiſe.

On the contrary, more modern philoſophers, as Wolfins, &c. have thought motion an active principle in matter, and which they have termed vis viva.

The reſiſtance Matter makes to Motion, is called its *vis inertiæ.*

To term a *negative quality* a *power* is not ſtrictly philoſophical, as being perfectly ſuperfluous, ought to be rejected as unneceſſarily embarraſſing the ſtudent's mind.

LAW II.

The change of Motion is in proportion to the force impreſſed; and takes place in the direction in which the force acts.

A quieſcent body receiving an impulſe, moves with a velocity in ratio to the power with which it is impelled.

Motion of any whole is the ſum of the motion of all the parts; it becomes doubled in a double body moved with equal velocity, and quadrupled in a double body moved with a double velocity.

Momentum (ſometimes called ſimply motion) is that force with which bodies change their place. This is always in proportion to the quantity of Matter multiplied by the velocity.

The battering-ram of the ancients being in weight 41,112 pounds, in a ſecond of time was moved one foot. A cannon-ball of 36 pounds moves 1142 feet in a ſecond of time: theſe multiplied produce 41,112, equal in power to the battering-ram.

LAW III.

Action and reaction are equal and contrary.*

Theſe three laws of Motion are aſſumed by Sir Iſaac Newton as the fundamental principles of mechanics, as ſuch are found to agree with all experiments and obſervations, are conſidered as mathematically true.

COMPOSITION AND RESOLUTION OF MOTION OR FORCES.

If a body be acted upon by any two ſingle impulſes, it will deſcribe the diagonal of a parallelogram, in the ſame time it would have deſcribed either ſide, had the forces acted ſeparately.

When a body is kept at reſt by three forces, they will be as the three ſides of a triangle, parallel to the direction in which they act. If ever ſo many forces acting againſt one another are kept in equilibrio by theſe actions, they may be all reduced to two equal and oppoſite forces.

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* To illuſtrate the law of action and reaction. According to Merſennus, a 24 pounder weighing 6400 lb. gives its ball an uniform velocity of 640 feet in a ſecond. The momenta of the cannon, and the cannon and the ball will be equal; hence 24×640 equal to 6400×24, ſo that on an horizontal plane the cannon would recoil near two feet and a half. Thus converſely by knowing the weight of a cannon and its recoil, the momentum of the ball is aſcertained.

Two forces acting at the ſame time on a body, in directions which are oblique to each other, do not move the body by that part of their force, which on account of their obliquity is oppoſite and contrary, but by what remains after the oppoſite forces are deducted.*

CENTRIFUGAL POWERS.

Bodies when thrown into motion, their tendency to recede from the centre of motion will be in the ratio of their momenta.

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* It was objected to Galilæo, when he aſſerted the motion of the earth from Weſt to Eaſt, a cannon ball ſhot upright, would not fall down in or near the place where it was ſhot. A ball fired out of a cannon elevated perpendicularly, and placed in a veſſel in full ſail, would fall down in the cannon's mouth.

So a ball dropt from the top of a maſt of a ſhip in full ſail, would fall directly to the bottom of the maſt.

The action communicated to theſe moving bodies, is the reſult of two forces, the propelling action, and the action or motion of the veſſel, &c.

illuſtrated by many experiments on the whirling table.

Thus a bottle of any liquor (which after having been muddy, is by length of time become fine, and is again made foul by ſhaking) may ſooner be brought to be fine by a centrifugal force, than by being ſet upright at reſt.

Upon the ſame principles the weights of the ſame body differ in different latitudes. The earth in its diurnal revolution, the velocity of matter is neceſſarily in the ratio of its proximity to the equator; this circumſtance influences the vibrations of pendulums ten times more than their expanſion by heat; firſt obſerved by Richer at Cayenne.

From this obſervation it was that Sir Iſaac Newton demonſtrated that the equatorial diameter is about $\frac{1}{120}$ greater than the polar diameter.

Under the equator, bodies are carried round with a velocity of 1040 miles in an hour.

This is farther illuſtrated by the appearance of Jupiter, which being a much larger planet than our earth, and its diurnal revolution being performed in leſs time, is neceſſarily a more oblate ſpheroid, or more reſembling an orange.

This was accurately aſcertained from teleſcopic admeaſurement by Mr. Pound, who found that the equatorial diameter of Jupiter is $\frac{1}{12}$ longer than the polar diameter.

Caſſini depending on ſome inaccurate meaſures of Picard, of the meridian from Paris to the Pyrenean Mountains, endeavoured to prove the earth was an oblong ſpheroid, or like an egg; whoſe polar axis exceeds the equatorial diameter by 34 leagues.

As theſe admeaſurements were made by a 10 foot ſector, where the 200th part of an inch anſwers to 8 ſeconds of a degree, the error of a ſingle ſecond would be equal to 130 fathoms.

To determine this diſpute, Louis XIV. at the requeſt of his miniſter Colbert, ſent Bongouer, Condamine, Don Ulloa to South America, Maupertuis, &c. to Lapland; they aſcertained the meaſures of a degree as follows:

Under the Line	56,753	toiſes
45 deg. lat. -	57,028	
Paris 49 deg. lat.	57,069	
51 & 52 deg. lat.	57,100	
Lapland - -	57,422	

A French toiſe being equal to 6,408 Engliſh feet.

When on any meridian line the altitude of the Pole is obſerved proceeding Northwards till the elevation is one degree more, or Southward till the height is one degree leſs, the diſtance between theſe two places is eaſily aſcertained by Trigonometry when the *fundamental baſe* is known.

CENTRIPETAL POWER, OR GRAVITATION,

Is the tendency of matter, with reſpect to terreſtrial beings, to the centre of the earth.

Copernicus regarded it as an *appetentia* that the Creator had impreſſed on all kinds of matter. Tycho Brahe, and his pupil Kepler, had ſome imperfect theories.

The cauſe of gravity is ſtill involved in impenetrable darkneſs. Dr. Halley refers it to the immediate agency of the Creator. Mr. Cotes deems it eſſential to matter, like extenſion and mobility. Newton attributes it to ſome undiſcovered and inviſible mechanical affection of matter, and rather ſuppoſes the exiſtence of ſome kind of æther, rarer within the denſe bodies of the ſun and planets, than in empty ſpace.

It is difficult to conceive a fluid ſubtle enough to penetrate the inmoſt receſſes of denſe bodies, and ſo rare as not to impede their motions, ſhould yet be deemed capable of communicating motion.

Fluids preſs according to the ſurface expoſed, while gravity is always in proportion to the quantity of matter.

To aſcertain whether ſuch a power as gravitation exiſted, Bougouer in 1738, when at Peru, tried the largeſt of the Andes, whoſe bulk to the earth was as 1 to 2000, there was no coincidence.

Dr. Maſkelyne more accurately tried this on the mountain Schehallien, in Perthſhire, and which conſiderably more influenced the vertical poſition of the plumb-line.

May not gravitation be the mechanical effect of the motion of the earth in its orbit? all terreſtrial bodies participating of the ſame impulſe, would hence have a tendency to perſevere in this motion, according to the quantities of matter.

Upon the ſame principle may be explained the different weights of the ſame body in different latitudes.

The earth in its orbit moves at the rate of 1,600,000 miles in a day, while it has a contrary motion round its axis from Weſt to Eaſt.

The portion of earth near to the Line moves about 1040 miles every hour. In the latitude of England, the motion of bodies is not more than

600

600 miles. At the poles of the earth there is no counteracting motion.

From this it would appear that a body weighing 70 pound at the Poles, would weigh a little more than 69 pound and a half in England, and 69 pound under the Line.

So that a body weighing 200 pound in England, would loſe near one pound when under the Line.

This circumſtance nearly coincides with experience, as Mr. Richer obſerved at Cayenne, from the tranſits of the fixed ſtars over the meridian, that his clock loſt two minutes, twenty-eight ſeconds per day, and hence it was neceſſary to ſhorten the pendulum one line and a quarter.

Four or five years after, Dr. Halley obſerved the ſame at St. Helena, and remarked that the increaſe of temperature would only have expanded the pendulum as to have required the 70th part of an inch, while the diminution of gravity obliged him to ſhorten it the 7th of an inch, or ten times more.

OF THE DESCENT OF BODIES.

WHEN a body near the ſurface of the earth is left to itſelf, it falls towards the centre of the earth with an accelerated force.

Galilæo firſt explained this, and demonſtrated that this increaſed as the ſquares of the times of deſcent.

Newton aſcertained, by letting a heavy body fall from the dome of St. Paul's, that it paſſed through 16 feet and one inch, in a ſecond of time.

A body at the end of its fall in one ſecond, if continued on with the velocity it acquires in the laſt inſtant of time (ſuppoſing a ſecond divided into a number of inſtants) would deſcribe double ſpace, as the gravitating power ſtill continues, being added to it, will make the deſcent in the ſecond moment 48 feet and a quarter, and nearly 80 feet and a half in the third, &c.

This impulſe acting with gravitation, occaſions the proportionate acceleration in the arithmetical ratio of 1, 3, 5, 7, 9, 11, &c.

A heavy body falling in the firſt moment will be 16 feet and a half, in the ſecond moment three times this number of feet, in the third moment five times, &c.

Five times added to three and one make the ſum of nine; by multiplying this by 16 feet and a half, will expreſs the ſpace it has gone through at the end of three ſeconds; as the ſquare root of nine is three, the ſpaces gone through will be as the ſquares of the times.

The percuſſive force of falling bodies may thus be aſcertained. One pound weight falling from the height of one foot, acquired a momentum at the end of its fall equal to three pounds, at four feet ſix times, ſixteen feet twelve times, thirty-ſix feet eighteen times.

Thus 500 pound falling from the height of ſixteen feet, would acquire a momentum at the end of its fall equal to three ton weight.

As the ſame time is nearly expended in the aſcent as in the deſcent of bodies, by obſerving the time elapſed between its being thrown up and its return, may aſcertain the height. Thus alſo the depth of a well or pit may be known, by letting a ſtone fall.

All bodies whatſoever fall with equal velocity, provided they paſs not through a reſiſting medium.

CENTRE OF GRAVITY.

In every body there is a certain point, which if ſuſpended, all the reſt are kept in equilibrio; this point is called the Centre of Gravity.

A line drawn from this point towards the centre of the earth, is called the Line of Direction. In this line all bodies will deſcend with equal velocity.

When inclined bodies are ſet upon an horizontal plane, they will fall the way they incline, if the Line of Direction does not fall within the baſe. When it does fall within the baſe, they may be conſiderably inclined, and yet ſupported; as is the caſe of the inclined tower at Bologna.

Exp. 1. Double cone rolls upwards, when the elevation does not exceed the radius of the baſe.

Exp. 2. The truncated cone for raiſing water from great depths, and emptying it in troughs.

Exp. 3. Bucket of water.

Exp. 4. Stick broke on two glaſſes.

Exp. 5. Inclined cylinder.

PENDULUM.

Any body hanging from a point is called a Pendulum.

Galilæo, from obſerving the ſwinging of his lamp, firſt remarked, that the vibrations, whether ſlow or quick, were performed in equal times; and hence thought it might be made uſe of as a meaſurer of time.

Huygens was the firſt who applied it to clocks.

A Pendulum 39 inches and two-tenths vibrates once in a ſecond; to vibrate once in two ſeconds, it muſt be 159 inches, or four times as long; ſo that the lengths will be as the ſquares of the times.

As Pendulums are ſubject to changes in the ſame latitudes, from diverſities of temperature, when expanded in ſummer will move ſlower; to remedy this there is a ſcrew placed at the bottom of the Pendulum, called a regulating bob, in order to adjuſt it.

To rectify this, various ſchemes have been adopted; metals expanding in contrary directions, in order to counteract each other, united in the form of a gridiron, others made of glaſs filled with mercury.

The length is taken from the ſuſpended point to the centre of oſcillation, the heavier the bottom part of the Pendulum is the more accurate.

MECHANICS.

Every thing is called a power which is capable of acting upon a body, and every power which can thus act upon matter is ſuppoſed to be material, without regarding any abſtruſe ſpeculations reſpecting its nature.

The mechanical powers are generally reduced to ſix: the Lever, Wheel and Axle, the Pulley, the inclined Plane, the Screw and Wedge. To theſe a ſeventh may be added, as one whoſe mechanical advantage is extenſive, and which cannot be reduced to any of theſe, viz. the Spring.

I. The LEVER.—Of theſe there are three ſpecies: firſt, when the preſs lies between the weight and power; as ſciſſars, pincers, ſnuffers, hammer, crow, &c. Second ſpecies, is when the weight is between the fulcrum and the power, as oars, doors, two men carrying a load upon a ſtick, &c. Third ſpecies, is when the power is between the weight and the fulcrum, as in rearing a ladder, ſo all the muſcles of the human body. In all theſe the power is to the weight inverſely, as their diſtances from the fulcrum.

OBLIQUE LEVERS.—-Theſe are adopted when the motions cannot be directly applied in the direction of the motion required, ſuch as windmills where the air acts in an oblique direction; ſo in water-mills, in pumps of all kinds where the crank is applied; in theſe caſes part of the real power muſt be applied to no efficient purpoſe, and the remainder only becomes the real motive force.

COMPOUND LEVER.—If the Levers are of equal power, whatever number there are combined, the united powers will be as the power of one Lever, whoſe index is the number of Levers.

This is ſaid to be the conſtruction of a machine of Archimedes: on this principle depends the weighing machines.

Second Mechanical Power, the WHEEL and AXLE. In this the power is to the weight, as the diameter of the Axle is to the diameter of the Wheel. If there are ſeveral Wheels ſo conſtructed that the circumference of one acts upon the Axis of the other, the power is to the weight as the ſum of the diameters of the Axles is to the ſum of the diameters of all the Wheels.

Thus in a watch, as the main ſpring unbends, the chain is proportionably removed from the Axis of the fuſee Wheel. In order to preſerve a regular movement, the fuſee is formed of that curve called the logarithmic curve, which correſponds to the progreſſive decreaſe of elaſticity.

III. INCLINED PLANE.—Power is to the weight, as the height of the Plane is to the length of its baſe,

IV. The PULLEY.—In a fixed Pulley, the power is equal to the weight. In this no mechanical advantage, except the conveniency of altering the direction in which the power is applied. If the ſame ſtring go round two ſets of Pullies in two blocks, the power is to the weight as unity is to the number of ſtrings at the lower block. In this the lower block is added to the weight. If each Pulley have a ſeparate ſtring fixed to ſomething immovable above, the power is to the weight, as unity is to that power of two, whoſe index is the number of moveable Pullies. Here all the moveable Pullies co operate with the weight,

Mr. White's Pullies conſiſt of two, each having many concentric grooves, whoſe diameters are in the ratio of their velocities: hence their revolutions are made in the ſame time, well calculated for deſtroying that ſhaking motion experienced in blocks of Pullies, from one Pulley moving ſo much quicker than another.

V. SCREW.—The power is to the weight, as the diſtance between any two contiguous threads is to the circumference deſcribed by the power.

The Screw is the ſtrongeſt of all the mechanical powers; the great diſparity between the velocity of the hand and that of the threads of the Screw, renders it very proper for dividing ſpace into a great number of parts; hence well calculated for the nice adjuſtment of microſcopes, teleſcopes, &c.

VI. WEDGE.—Hamilton, Deſaguliers, Emerſon, Muſchenbroek, and Graveſand aſſert, that the power is to the reſiſtance as one half the back is to the height; whilſt Keil, Whiſton, and Nicholſon aſſign this ratio to be that of the whole back to the height. In both theſe caſes it is ſuppoſed the power acts parallel to the baſe.

Experience does not coincide with theory. Apply a ton weight upon a Wedge and it will not penetrate, whilſt the impulſe of a child will make it enter. The impulſe excites a vibratory motion in the conſtituent parts of the body, and in the inſtant of relaxation the Wedge enters; while in the ſucceſſive inſtant the conſtituent particles meeting thus with a reſiſtance to their re-action, exerts a force which tends to further ſeparation.

Seventh Mechanical Power, the SPRING.—From this, great mechanical advantage is derived in variety of inſtruments, particularly in carriages. Thus in the rough roads of Cheſhire, a pair of horſes can draw a carriage upon Springs better than four horſes could without. Springs in this caſe accumulate a kind of motion, which facilitates the progreſſive one ſimilar to flys, and vibrating balances which in clock-work accumulate the ſuperfluous power, and impart it occaſionally to equalize the motion.

FRICTION.

In proportion to the quantities of matter, and not the ſurfaces. The doctrine of Friction, Wheel, &c.

OPTICS.

Rays of Light proceed from luminous bodies in right lines and in all directions.

Whether Light is univerſally diffuſed, or emanates from the Sun, is a ſubject much controverted ed by philoſophers. Des Cartes, Huygens, Euler, Dr. Franklin, and many others, have ſuppoſed Light is univerſally diffuſed, while Roemer, Newton, and the generality of philoſophers deem the Sun the ſource of this fluid.

If Light were univerſally diffuſed, the ſame effects do not take place from an impreſſion as in other diffuſed fluids, " Preſſio non propagatur per fluidum ſecundum Lineas rectas, niſi ubi particulæ fluidi in directum jacent."

Roemer has aſcertained from the eclipſes of the Jovial Satellites, that Light is progreſſive in its motion; that it required eight minutes and a few ſeconds to paſs from the Sun to the Earth. Theſe obſervations have received additional confirmation from their coincidence with the celebrated diſcovery of Dr. Bradley, reſpecting the aberration of the ſtars. Light is material.

Although objections may be made to theſe experiments, which have been brought forwards as proofs of the momentum of Light, as the agitation of aſbeſtos, feathers; delicate braſs vanes, ſuſpended on harpſichord wire, being thrown into motion; yet the evident effects produced by its combination with many bodies, are great proofs of its materiality.

Franklin ſuppoſed that any particle of matter, however ſmall, moving with a velocity of near

200,000 miles in a ſecond of time, that its momentum would be equal to a 24 pounder diſcharged from a cannon.

If we ſuppoſe a luminous particle, equal in bulk to the minuteſt portion of volatile effluvia, which can be calculated, the force of motion in each particle would be infinitely inferior to the momentum of the gentleſt dew.

Light is a fluid ſui generis. Bodies may be heated from 540 degrees down to 60 degrees without exciting any ſenſible illumination; while on the contrary, we ſee Light from the ſlow phoſphoreſcent combuſtion of the lanthorn-fly and the glow-worm.

Fire is diffuſible equal, and penetrates all bodies without exception, while Light only produces ſenſible effects on opaque matter. Fire, unleſs very intenſe, produces no change in the colourleſs nitrous acid, while Light gives it another tinge, and renders it fuming.

Light blackens the oxyds of ſilver, mercury, and biſmuth, whitens the ſulphurated calx of antimony, gives the purple colours to the juice of the murex, the violet to the decoction of archil and trefoil.

Animals confined in obſcurity become white, from the Arctic bear to the larvæ of the minuteſt inſect: the tree frog, brought from its dark receſs, changes from a dirty yellow to a dark green. The infant negro and native American are fairer than their parents; and their change of colour is attributed, by Dr. Bancroft, to a combination of Light with their reticular membrane.

The French chymiſts, from not finding any volatile alkali or phoſphoric ſalts in fœtal fluids, have hence ſuppoſed Light to be a neceſſary ingredient in theſe ſalts.

Thus the human ſpecies become pale from confinement, and Girtanner has found that pale animals and white plants are peculiarly weak.

Sometimes there appear exceptions to this, as various plants and moſſes, as the *poa annua et compreſſa*, *plantago lanceolata*, *tripolium anuenſe*, *cheiranthus cheiri*. Lichen vertrillatus are of a green colour, though growing in the galleries of mines. But Sennebier, Ingenhouſz, Rozier, &c. attribute this to the azotic and inflammable air; that the latter contains a quantity of Light, when inflammable air is joined with pure air, increaſe the green colour.

Teſſier has remarked that potatoes, when guarded from Light, mix their roots and young branches indiſcriminately.

Plants, when expoſed to Light, ſecrete pure air; in the night time they evolve impure air.

The effect of Light in cryſtallization is very evident, the cryſtals are better formed; in this caſe it appears to diſengage the electricity of the cryſtal, and thus influencing the arrangement.

The heliotropii, and many of the ſun-flower claſs, turn with the Sun, and move with that luminary; when he is depreſſed below the horizon, the flowers cloſe their leaves, and fall into a vegetable ſleep.

The diamond and many other gems have the property of abſorbing Light, and of giving it out in the dark.

REFRACTION.

Every phyſical point of a luminous object, has rays of Light proceeding from it in every direction; when theſe rays enter into any medium obliquely to the plane, their rectilinear courſe is changed, and bend from the right line in that point where they enter the different medium.

In thoſe tranſparent ſubſtances, which are not inflammable, this refraction is nearly in the proportion of their ſpecific gravities.

When a ray of light enters into a denſer medium, it becomes refracted towards the perpendicular; when into a rarer, the oppoſite.

Thoſe tranſparent ſubſtances which are inflammable, a ray of Light in its paſſage through them ſuffers a greater refraction than in the ratio of their denſities.

Thus in our atmoſphere, conſiſting of infinite aerial ſtrata of different progreſſive media, a ſolar ray meets with a continual refraction towards the perpendicular, and conſequently deſcribes a convilinear line.

In the ſame medium, however the rays of Light may vary in their obliquity, the refracted ray bears univerſally the ſame proportion to the incident ray.

A ray of Light paſſing out of air into water, when refracted the ray approaches the perpendicular in the proportion of three to four, out of air into glaſs as three to two.

This proportion always holds good, whatever may be the form of the medium.

When a glaſs is a plane ſurface, one perpendicular to any one part will be parallel to a perpendicular to any other.

When any other figure, this varies, and the perpendicular muſt be taken from that point of the curve where the ray enters.

If this curve is regular, having one and the ſame centre, the refractions in every part will ſo take place with the ſame degree of inclinations towards the axis of the lens, as to unite in one and the ſame point.

As the perpendicular line to any point is always drawn from the centre of the curve through that point, the more convex the lens, the leſs diſtance there muſt be between the circumference and the centre, and conſequently the refracted ray muſt unite ſooner in the axis.

The point where all the rays unite, is called the focus. A burning lens muſt be convex, all the Light which is thrown upon its ſurface is condenſed into a ſmall circular ſpace ; the united rays produce effects in proportion to the extent of ſurface. This point varies according to the diſtance of the object from which the rays of light are evolved.

Hence it is very eaſy to calculate the focus, when there are given the diſtance of the object, the refracting power of the medium, and the radius of the curve.

If a glaſs lens be very large, by meaſuring the thickneſs of the edges and of the middle, the focal length is eaſily aſcertained. It will be as the difference between the thickneſſes of the middle and of the edge, is to half the breadth, ſo is half the breadth to the focal length. If a glaſs ſphere, the focus will be $\frac{1}{4}$ of its diameter diſtant from the vertex. In a plano convex, the focus will be $\frac{2}{3}$ of its thickneſs nearer when the rays fall on the convex ſide, than when they fall on the plane ſide. In a very thin glaſs lens, half the breadth is a mean proportional betwixt its thickneſs and focal length.

When an object is placed before a double convex lens at any diſtance greater than the radius of the ſphere, the image will be inverted.

CONCAVE LENS.

As convex glaſſes cauſe the rays of Light to converge and unite, ſo thoſe which are concave make them ſeparate and diverge.

As concave glaſſes do not collect the rays, they have not a real focus, as the rays after they have paſſed through ſuch glaſſes do flow in ſuch a manner as that they either tend to ſome point behind the glaſs, or appear to flow from ſome point before it; theſe points are uſually called the foci.

If rays which are converging towards a focus be interrupted by a concave lens, whoſe diſtance from the focus is equal to the radius of its concavity, after they have paſſed through the glaſs they will ceaſe to converge and become parallel.

CATOPTRICKS.

A RAY of Light falling on a mirror is reflected in an angle equal to the incident one.

If an object be placed before a concave ſpeculum at an infinite diſtance, the image will appear on the ſame ſide of the ſpeculum as the object. This is called its focus, when converging the parallel rays of the Sun. As the object approaches the ſpeculum, the image recedes; and when ſo near as to be at the centre, both will coincide; as the object paſſes the centre towards the glaſs, the image is projected towards the centre; and when but half the radius diſtant, the image is at an infinite diſtance, or proceed parallel, and the ſpeculum will ſeem to be in flames; when the diſtance is leſs than half the radius, the image appears behind the ſpeculum.

CONVEX SPECULUM.

The poſition of images ſeen by reflection always appear erect, the ſeveral parts of the image have the ſame ſituation with the correſponding parts of the object, and of conſequence the image appears erect.

COLOURS.

Rays of Light have hitherto been conſidered as undergoing no change from refraction. Newton has ſhewn that a ray of Light conſiſts of different portions, which differ in degrees of refrangibility, which portions poſſeſs colours laſting and permanent, ſo as not to be changed either by refraction or reflection.

When a ray of Light paſſes through a glaſs priſm, that portion which is the leaſt refracted will be red, the next orange, yellow, green, blue, purple, and violet.

It is owing to this that no convex glaſs can converge rays of Light to a ſimilar point from which they originated, but forms a circle of ſome aberrations.

Owing to theſe different refractions they cannot all unite in the ſame point of the axis, but will form a circle of certain dimenſions.

This deviation from a point is called the aberration. The ſpace is $\frac{1}{18}$ part of the ſurface through which the rays of Light have flowed. Theſe aberrations are divided into two, viz. the longitudinal and lateral aberrations.

The refractive qualities of different kinds of glaſſes, with reſpect to the divergency of colours, are not in the ſame degree of ratio.

This property was firſt aſcertained by Mr. Dollond, who found that white flint glaſs diſperſed the rays, after refraction, one-third more than crown glaſs.

By Two wedges of glaſs, one of flint of twenty degrees, and the other of crown of thirty degrees, the Light would be refracted but not coloured.

By combining in this proportion a convex glaſs of crown, and a concave one of flint, there would be a refraction without any colouring; as the exceſs of refraction is in the convex, the rays of Light would be converging.

RAINBOW.

ARISTOTLE knew it was produced by watery drops; he thought a ſingle particle was too ſmall to reflect the whole image of the Sun: hence, he ſays, the colour is only exhibited, and not its proper figure.

Seneca and Vitellio ſuppoſed the colours of the Rainbow to be three, and produced by a mixture of the brightneſs of the Sun's Light with the blackneſs of the cloud from which it is reflected. Porta thought the Rainbow produced by the refraction of Light in the whole body of Rain or Vapours, but not in the ſeparate drops.

In 1571, Fletcher of Breſlaw, endeavoured to account for theſe colours, by means of a double refraction and one reflection; he did not imagine that theſe circumſtances took place in one drop, that it ſuffered a refraction at its entrance and at its exit, and was afterwards reflected by another drop before it reached the eye.

In 1611, Antonio de Dominis, a biſhop, firſt advanced that the double refraction of Fletcher with an intervening reflection, were ſufficient to produce the colour of the Bow, and to bring them to the eye of the ſpectator.

Not knowing the different refrangibility of the coloured rays, he endeavoured to explain theſe colours by ſuppoſing the red rays had traverſed the leaſt ſpace in the inſide of a drop of water, and therefore retained more of their native force, and produced a ſtronger ſenſation: he had alſo obſerved that one drop ſends one colour to the eye, another drop another colour, as the eye was not wide enough to receive rays of all colours from the ſame drop.

As all the rays of ſimilar colours muſt leave the drop of water in a part ſimilarly ſituated with reſpect to the eye; hence each of the colours muſt appear circular.

The external Bow he imagined was formed by the higher part of the Sun's diſc, and the interior Bow by the lower part.

Des Cartes ſhewed the outer Bow was produced by two reflections and two refractions in the ſame drop of water.

Newton, after aſcertaining the refrangibility of the coloured rays, applied his reaſoning to the explication of theſe phænomena.

The moſt refrangible rays form an angle with the Sun and the eye, of 40 deg. 17 min. and the leaſt refrangible rays of 42 deg. 2 min. in order to conſtitute the lower Bow; the difference will give the width by conſidering the Sun as a point, as it ſubtends an angle of 30 minutes, this muſt be added to it.

In the ſuperior Bow the leaſt refrangible rays will have an angle of 50 deg. 51 min. and the moſt refrangible 54 deg. 7 min. As theſe angles are reverſed, the colours muſt be alſo; and hence the diſtance between the Bows will be 8 deg. 49 min.

Sometimes a third Rainbow has been ſeen. Celſius deſcribes one larger than the other two, and interſecting them. Mr. Edwards ſaw one ſome time after the Sun had ſet.

Halos or Corona, are luminous circles ſurrounding the Sun, Moon, and Planets, varying in their ſize or extent. Muſchenbroek ſays, in Holland fifty may be ſeen in a day. Des Cartes imagined they were produced by the refraction of Light in round particles of ice floating in the atmoſphere. Gaſſendus ſuppoſed it was owing to the ſame cauſe as Rainbows.

Huygens invented a laboured hypotheſis, which has been adopted by Newton and Smith. Theſe ſuppoſed there were in the atmoſphere tranſparent bodies with opaque nuclei, formed by ice without and ſnow within.

Halos or Coronas we may form at pleaſure, by placing a candle in the midſt of ſome ſteam, or beyond a receiver during the proceſs of exhauſtion, and viewing the Light through the cloudy precipitation.

PARHELIA, OR MOCK SUNS.

ARISTOTLE mentions two, Scheiner ſaw four at Rome which were the firſt that excited the attention of philoſophers. Muſchenbroek ſaw the ſame number at Utrecht, and in 1661 Hevelius ſaw ſeven at Sedan; their apparent ſize, equal to the true Sun, are externally tinged, and many have a fiery tail. Dr. Halley mentions one with tails each way.

Sometimes three Suns have been ſeen in the ſame vertical circle, well defined, and touching one another, the true Sun in the middle.

In 1771, Mr. Baxter at Fort Glouceſter in America, on January 22d, the froſt ſevere, ſaw five; at firſt he obſerved a large circle round the Sun, with two Parhelia as brilliant as the original Sun; a little more than one-third from the horizon to the zenith a beautiful enlightened circle parallel to the horizon, which went quite round, till the two ends met in the circle ſurrounding the Sun; directly oppoſite to the Sun a luminous croſs, and in its interſections a Mock Sun; near the zenith was a beautiful Rainbow, with its convex ſide oppoſed to the Sun.

Theſe phænomena are attributed by Dechales to reflections of the image of the Sun, from clouds properly figured and well defined.

PARASALENES

Are ſimilar phænomena reſpecting the Moon.

EYE.

The parts of the Eye neceſſary for explaining the manner of viſion deſcribed. The Cornea, the Aqueous Humour, the Iris and Pupil, the Cryſtaline Lens, its ſurrounding Capſule, and the Ciliary Zone, the Vitreous Humour, the Retina, Pigmentum, Choroid Coat, and the Optic Nerve.

A ray of Light coming from a luminous body, or reflected from any object, falls in ſuch a manner upon the Tunica Cornea of the Eye, as to form a ſharp cone between the lucid point and the membrane on which they are ſpread. The Cornea, by being ſpherical, admits of an infinite number of perpendicular rays, whilſt if it had been of a plane ſurface, could only have admitted of one; on this account viſion would have been much limited, for rays would then have entered ſo obliquely, inſtead of being refracted would have been reflected.

In inſects who are deprived of motion of the head, is beautifully reticulated, each portion being a part of a diſtinct ſphere, in order to produce a quick convergency of ſurrounding rays. In flies it is eaſy to count three thouſand interſtices. Lewenhoek imagined they were ſo many diſtinct Eyes; there is only one Cryſtalline Lens common to them all.

The Cornea itſelf being a meniſcus glaſs, like all media of a curvilinear nature whoſe correſponding curves are concentric, the refraction in the entrance is ſo corrected by the refraction in the exit, as to render the emergent ray in the ſame line of continuation with the incident one.

As between the Cornea and the Iris there is interpoſed a fluid of nearly the ſame denſity with water, this renders the Cornea a plane convex

Lens, which form cauſes the rays to converge after their entrance.

The Aqueous Humour, by being fluid, allows of a free and eaſy motion to the dilatation and contraction of the Pupil. Fiſhes have a very ſmall portion of this fluid, in them it would be uſeleſs, as they are ſurrounded by an equally denſe medium.

The rays thus gently converging, paſs through the perforation of the Iris, called the Pupil, which in all animals intended to ſee equally every way is orbicular, a form which allows of the tranſmiſſion of the greateſt quantity of Light in the leaſt ſpace. In the Iris of a greyhound, the two range of muſcular fibres are very viſible, one order radiated, and the other orbicular concentric to the Pupil; the former by contracting dilate the Pupil, the latter diminiſh it.

Theſe fibres are exquiſitely ſenſible, and preſerve the Retina from being too much injured, by thus regulating the intenſity of Light.

It is by this we diſtinguiſh whether a cataract or opaque cryſtalline be combined with a Gutta Serena; if we obſerve no coincident contraction of the Iris of the diſeaſed Eye from the ſympathiſing influence of the other, the removal of the Cryſtalline would then afford no relief.

If this fibrous contraction were in the proportion of the weakeſt Light to the ſtrongeſt, the degrees of contraction would then be one million of times; the faint glimmering of a diſtant candle to the unclouded rays of the meridian Sun is as 1 to 1,000,000.

Some animals have a voluntary power over the Pupil, as the cat, &c. Dr. Goddard tells us that the camelion not only can dilate one without contracting the other, even look upwards with one Eye, while downwards with the other.

The rays, after having paſſed through the Pupil, enter the Cryſtalline Lens, a medium of a denſer nature, and beautifully formed of two elliptical convex portions, the anterior flatter than the poſterior, compoſed of concentric Lamina, the external Lamina being of a ſoft mucilaginous nature, the interior more compact, till at laſt they form a ſort of continued Nucleus.

The ſpecific gravity of the whole Lens is leſs than the ſpecific gravity of the Nucleus. This different denſity of the conſtituent parts is admirably contrived for correcting the aberration from its figure, as well as of the Cornea, &c. The rays in each pencil are more and more remote from the Axis, by paſſing through a medium gradually diminiſhing in denſity from the middle towards the extremes, have their foci gradually lengthened, which corrects the aberrations of the figure, that ſo they may all unite nearer together.

The aberrations ariſing from figure of a ſmall Lens is inconſiderable to the aberrations cauſed by the unequal refrangibility of the rays of Light.

Euler ſuppoſed the Eye perfectly achromatic, while Dr. Maſkelyne has attempted to calculate the circle of aberrations upon the Retina to be .002667 of an inch; he thinks ſome ſuch aberration neceſſary to account for the ſenſible diameters of ſome of the fixed Stars.

The rays, after paſſing through the Cryſtalline enter the Vitreous Humour, which being nearly of a ſimilar denſity, produces no alteration in the refraction.

Its uſe ſeems principally to preſerve the ſpherical form of the Eye, and to keep the Retina at an equal diſtance from the Cryſtalline.

The rays of Light converge in the very points they emerge from the Vitreous, which is immediately covered by the expanſion of the Optic Nerve, termed the Retina.

The Retina, when examined by a high magnifying power, appears like a piece of pluſh, with the ends of the threads turned towards the Cryſtalline.

A circle

A circle facing the Eye, ſubtending an angle of one minute, its diameter on the Retina will be $\frac{1}{5340}$ of an inch, ſuppoſing the interſection of the rays to be juſt as they emerge from the Cryſtalline; this coincides nearly with the intervals between two fibrils.

Thoſe who can ſee remote objects more diſtinct than others, have the intervals between the fibrils leſs. Muſchenbroek informs us of one man who could count 13 Stars in the Pleiades, and Mæſtlinus could diſtinguiſh alſo with the naked Eye, three Satellites of Jupiter.

How to aſcertain Diſtance.

If the admeaſurements of the different parts of the Eye given by Monſ. Petit are correct, perfect viſion will be at 24 inches. Rays of Light proceeding from this diſtance will be converged on the Retina, without any alteration of the Eye.

If the object ſhould be nearer, the rays of Light would be more diverging, and would not be converged on the Retina without ſome change in the Eye; ſo Light from objects remotely ſituated, by being parallel, would be converged too ſoon.

To make the requiſite change, the muſcles ſurrounding the Eye, or any alteration of the Cornea, would be inadequate; if the exterior curvature of the Cryſtalline Lens be rendered equally convex with the poſterior. Rays of Light from near ſituated objects would be converged; if the poſterior curvature ſhould be reduced to an equality with the anterior, parallel rays would be converged.

In theſe changes the ſurrounding Capſule would occaſionally become corrugated; this is prevented by the Ciliary Zone, which by its occaſional contraction prevents this.

In fiſhes nature makes the change only in this part; thoſe who have ſuffered an extraction of this Lens, are obliged to make uſe of glaſſes of different convexities, proportioned to the diſtances.

The mind, from experience, aſſociates the diſtance of the object with theſe reſpective changes, as far as theſe occur, forms an idea of the remoteneſs or proximity of an object.

Marriotte finding a piece of paper is loſt to the Eye, whoſe diameter is about the tenth part of its diſtance from the Eye; the angle thus formed by the interſected ray and the internal baſe, correſponds to the diameter of the Nerve: from the inſenſibility of this part of the Retina, he hence imagined the choroïdes was the ſeat of viſion.

The Near-ſighted and Long-ſighted Eye.

The Eye, like other parts of the human body, from any continued uniform action, acquires permanently that ſtate as to be with difficulty changed; thus ſailors, countrymen, travellers, &c. from looking at remote objects, become long-ſighted, and with difficulty can accommodate the Eye to near ſituated objects: ſo on the contrary, ſtudents, watch-makers, &c. become near-ſighted. The former is more generally the reſult of age, ariſing from the general reduction of the whole ſyſtem, the Eye participating of it, no longer preſerved in its full orbicular form, no longer the uſual animating convexity, ſinking within the orbit, the powers of convergency are thus diminiſhed, a glaſs of a proper degree of convexity muſt be adopted.

So the near-ſighted is more frequently congenite, to remedy which a concave glaſs muſt be uſed.

*Theory of Spectacles.**

Strabism or ſquinting is of two kinds, one ſpecies of it curable.

Impreſſions on the Retina remains a certain time; obſervations of Newton and Biſhop of Llandaff.

Inflection of Light.

Why Stars ſcintillate.

The circulation of blood in the Eye rendered viſible.

Ocular Spectra, an examination of De la Hire and Dr. Robert Waring Darwin's opinions.

An enquiry into the ſingular terreſtrial refractions, termed by ſailors Looming, the obſervations of Ellicott and Coxe.

The advantages of two Eyes; objects not only appear a little brighter, cannot be loſt to both Eyes at once; for when the image of an object falls upon the Optic Nerve of one Eye, it will fall at ſome diſtance from it in the other; alſo the field of viſion is conſiderably increaſed.

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* The Rev. Mr. Stark, in the Iriſh Memoirs, thinks defective ſight may in ſome reſpects be owing to the want of that gradation in the denſities of the parts of the Cryſtalline; he recommends a concavo-convex glaſs, whoſe greater curvature is on the convex ſide.

The effects of motion; a ſmall object in motion is eaſier diſcerned than if at reſt. A Star is ſooner perceived by agitating a little the teleſcope.

The luminous appearance of the Eyes of animals with dilated Pupils, as cats, owls, &c. is owing to the Pigmentum not being black; the rays are reflected from the concave ſurface, and unite in a point on the poſterior part of the Cryſtalline Lens; thus being placed nearer to the Lens than its focal diſtance, the rays continue diverged and diffuſed, and thus illuminates the Lens.

White animals have no pigmentum, the redneſs which is ſeen is from the choroïd veſſels turged with blood; when the animal dies the redneſs diſappears, from the choroïd veſſels collapſing.

MICROSCOPES.

By theſe inſtruments we are enabled to examine the minute and wonderful works of the creation, to unfold the admirable ſtructure of animals and vegetables, and diſplay the exquiſite texture of their conſtituent parts.

The ancients were acquainted with the burning power of glaſſes; the ſurgeons with glaſs ſpheres uſed to cauteriſe wounds, and veſtal virgins thus kindled their ſacred fire.

The ſpecula of Julius Cæſar and of Ptolemy, were only watch-towers.

Friar Bacon and Alhazen ſeem to have been acquainted with the magnifying powers of glaſſes; he mentions how he could make a boy appear like a giant, and a man a mountain, and the celeſtial luminaries to deſcend in any direction.

Although the magnifying power of a ſingle Lens might be known to Bacon, the application of a ſmall Lens to the examination of bodies took place in the 16th century. Fontana lays claim to it in 1618, ſome ſay Zachary Janſen and others Drebelius, who firſt made compound Microſcopes.

Thus a ſimple Microſcope conſiſts of a ſingle ſmall convex Lens, interpoſed between the Eye and the object. The magnitudes of objects are regulated by the diſtance they are from the Eye; if an object is placed at one inch from the Eye, the appearance is confuſed and indiſtinct, the rays are too diverging to be converged by the Eye; if a convex Lens, whoſe focal diſtance is one inch, the rays after being refracted will enter the Eye parallel; if eight inches be the neareſt point of perfect viſion, by means of the glaſs it will be ſeen eight times nearer, and conſequently enlarged eight times every way. If $\frac{1}{20}$ of an inch, the object will be 160 times nearer, and conſequently its ſurface 25,600 times greater.

Theſe Lewenhoek made uſe of. Mr. Gray invented a little glaſs ſphere, filled with water; he alſo perforated a piece of lead with a pin, and placing a drop of water on it, he could ſee any animalcule which might be in.

Compound Microſcopes.

When there is more than one Lens is thus termed.

In this caſe the image of the object is viewed, and not the object. The object is placed farther from the Lens than the focal diſtance, ſo that after refraction the rays converge, aud where they unite, the image of the object is formed; this image is viewed through a convex Lens, ſo placed that its focus ſhall be the place of the image.

This combination increaſes the field of view; ſtill further to increaſe this, a ſecond and a broader eye-glaſs is placed between the two others, which converges the rays from the object-glaſs much ſooner.

When theſe were firſt uſed, they were held in the hand, the object illuminated by the window; Culpepper added the reflector. For viewing opaque objects, we are indebted to Mr. Lieberkulen, by means of a ſmall concave reflecting mirror, perforated in the centre, in which the object Lens is placed.

Solar Microſcope,

Is a Wilſon's Microſcope, the object ſtrongly illuminated by the Sun, the rays concentrated by a convex Lens, invented by Mr. Lieberkulen; Æpinus added the mirror. The object thus being ſtrongly illuminated, will bear with diſtinctneſs a conſiderable magnifying power, which will be as the focal diſtance of the glaſs to the diſtance of the Screen.

TELESCOPES.

The invention of theſe uſeful inſtruments was caſual, to whom it ſhould be aſcribed authors differ, ſome give it to Metius, a Dutchman, about 1609; others to Lippenſheim, of Zeland, a ſpectacle maker, from caſually holding two convex ſpectacle glaſſes in a certain poſition; Borellus gives it to Zacharias Janſen. Fifteen years before any of theſe, Baptiſta Porta gave ſome ſketches.

The firſt were about one foot and a half. Galilæo from the confuſed report made one, as being the firſt who philoſophically employed it, by many has been deemed the diſcoverer; the firſt he had, magnified only three times, the next eighteen, afterwards one thirty-three, with which he diſcovered the Satellites of Jupiter, and the ſpots on the Sun's ſurface: the Teleſcope he uſed was a convex glaſs and a concave one.

The principles of a Teleſcope and Microſcope are the ſame; as Teleſcopes are intended to view remote objects from whence rays proceed parallel, an object glaſs of a ſmall degree of convexity is ſufficient.

Father Scheiner firſt made uſe of two convex glaſſes, from an hint of Kepler's; in this terreſtrial

trial objects are neceſſarily inverted, will appear diſtinct, and with a conſiderable field of view. The magnifying power will be in the ratio of the focal length of the object-glaſs to the focal length of the eye-glaſs, the ſame whether the eye-glaſs be concave or convex.

Rays proceeding from the eye-glaſs to the Eye are nearly parallel, a direction proper for to be converged on the retina in the natural Eye; to the near-ſighted perſon the eye-glaſs muſt be put in nearer the object-glaſs, in order to render the rays after their emergence a little diverging.

When a number of eye-glaſſes are uſed, the field of view is increaſed, although the number of refractions are greater, yet the ſum of the aberrations ariſing from the figure is leſs.

Although each Lens has its image, either real or imaginary, yet in general there are only two real ones, the firſt inverted, the ſecond upright. When the number of real images is even, the object will be ſeen upright; when that number is odd, the object is inverted.

All that is eſſential, is that the rays of the ſame pencil which enter parallel, ſhould emerge parallel; the intervals and focal lengths of all the Lenſes, except one, may be aſſumed at pleaſure, from whence that one muſt be determined.

Imperfections of Glaſſes.

The principal imperfections are two, one ariſing from the figure of the glaſs, the other from the different refrangibility of the different colours.

Aberration ariſing from Figure.

When a convex glaſs is formed of curves which are portions or ſegments of a ſphere, the rays of Light which fall near the edges of the Lens are ſooner converged than thoſe rays which fall nearer the Axis; hence between theſe extremes there will be a number of images.

The larger the ſegments the greater their diffuſion. On this account ſome opticians limit the arch to twenty degrees of its reſpective circumference. For the object-glaſs of a Teleſcope this is too great, although the diſperſion of the rays might be very ſmall, the magnifying power multiplies it as often as the object itſelf.

This aberration is but inconſiderable to that which ariſes from the different refrangibility of the priſmatic portions.

Philoſophers, previous to the time of Newton, attributed this to the figure of the Lens. When

Des Cartes ſhewed that glaſſes figured according to the ſurface deſcribed by conic ſections turned about their axis, would not have that effect,* then mathematicians turned their attention to grind glaſſes of ſuch forms, and among the reſt Newton himſelf, till his diſcoveries in 1668.

If a red object is placed at a diſtance from a convex Lens, the image will be farther from the Lens than if the colour of the image had been violet; the diſtance between theſe two images would be the meaſure of the aberration; if the object is of an heterogeneous colour, this ſpace will be filled by images of the intermediate colours.

This diſperſion is about the $\frac{1}{28}$ part of the focal diſtanee, a Lens of ſeven feet focal diſtance, the diſperſion would be about three inches.

The error ariſing from this diſperſion, is to that from the aberration of the figure as 5449 to 1. The diameter of the circle in the middle ſpace between theſe two foci is about the 55th part of the diameter of the aperture of the glaſs; and were it not that the orange, yellow and green occupied the central part, and being the moſt vivid, objects would not appear in the leaſt diſtinct. Hence the greater the focal diſtance of the object-glaſs is, the leſs muſt be the proportion which the focal diſtance of the eye-glaſs may bear to that of the object-glaſs; as the degree of confuſedneſs is as the breadth of the object-glaſs, ſo the magnifying power of the eye-glaſs muſt be in that degree.

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* Des Cartes, in his Dioptrics, demonſtrated that if the foci of two oppoſite hyperbola, whoſe axes were in the ratio of the ſines of incidence to refraction, if one of theſe hyperbolas be turned about its axis, and a portion of the ſolid ſo generated be cut off by a plane perpendicular to the axis, then all the rays which fall perpendicular upon this plane will be refracted by the convexity on the oppoſite ſide to one and the ſame point.

Thus an object-glaſs of four feet focus will admit of an eye-glaſs of one inch, and conſequently magnify forty-eight times. An object-glaſs of forty feet focus will only admit of an eye-glaſs of four inches focus, and only magnifies 120 times; and one of 100 feet will only bear one of 6 inches, and this only magnifies 200 times.*

On this account Newton deſpaired of improving refracting Teleſcopes, and hence turned his attention to reflecting Teleſcopes.

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* If the aperture of an object-glaſs be not as the ſquare root of the power of magnifying, the image will want Light; the ſquare root of the power of magnifying will be as the ſquare root of the focal diſtance of the object-glaſs, and therefore the focal diſtance of the eye-glaſs muſt be only as the ſquare root of that of the object-glaſs.

Euler tried by making the object-glaſs of two materials to correct this refraction; the diſcovery was reſerved for Mr. Dollond in 1757, who demonſtrated that the diſperſive powers in different glaſſes were not the ſame; thus flint glaſs diſperſes more than crown glaſs. Mr. Zeiher of Peterſburg attributes this to the minium it is combined with; he proceeded in the manner already ſhewn in the analyſis of convex Lens.

Reflecting Teleſcopes.

Merſennus firſt ſuggeſted them to Des Cartes, who treated the idea as ridiculous. Mr. Gregory, of Aberdeen, has been deemed the inventor, this he propoſed in 1663, viz. a concave ſpeculum, reflecting the rays from an object towards a ſmall ſpeculum, and this returning the image to an Eye placed behind the great ſpeculum; Newton was a workman, five years after he began one, and in 1672 completed two ſmall reflectors. The Academy of Sciences endeavoured to depreciate Newton by a diſguiſed Gregorian Teleſcope, under the name of Caſſegrian, with this difference, the ſmall ſpeculum was convex.

Thoſe Newton made were only ſix inches long, yet magnified equal to a ſix feet refractor; the difficulty of poliſhing made near forty years elapſe before another was made. Thus Mr. Hadley made one five feet long, after the Gregorian manner, and now from the improvement of Mr. Short and Mudge, a good poliſh alſo the proper parabolic figure are now given.

The powers of magnifying are as the focal diſtance of the large concave ſpeculum exceeds that of the eye-glaſs.

Newton's reflector was inclined to an angle of 45 degrees to the axis of the larger, in this not ſo great a quantity of Light is loſt ; on this account Dr. Herſchel has adopted it.

Binocular Teleſcopes. Dr. Blair's Teleſcopes. Opera Glaſs. Magic Lanthorn. Camera Obſcura. Hadley's Quadrant, &c.

PNEUMATICS.

The ſcience of Pneumatics, in the original derivation of the word, implies an inveſtigation into a ſomething of a ſpiritual nature: in this point of view the ancients conſidered that vaſt aerial volume that ſurrounds us, they ſuppoſed it a principle diveſted of the common properties of matter. Ariſtotle ſeems to have been the firſt who aſcribed Gravity to Air, the demonſtration of which was reſerved for Galilæo, Torricellius, and Merſennus.

All the philoſophers, till within this century, imagined that there were only one kind of aerial fluid, and that its various ſtates depended on the admixture of extraneous ſubſtances: thus Van Helmont was acquainted with the inflammable qualities of ſome Vapours, and knew that others extinguiſhed flame and ſuffocated animals; he had no idea that theſe ſubſtances were capable of being ſeparately exhibited in the form of a permanently elaſtic Vapour not condenſible by Cold.

Boyle obſerved that the elaſtic fluid extricated from ripe fruits, fermenting and effervescing liquors, extinguiſhed Flame, &c.

The

The ſagacity of Newton had obſerved that there were a ſomething in common Air neceſſary to Life, and which he called the ſpiritual part, and conjectured that Comets might occaſionally renew what was deſtroyed by reſpiration. Dr. Hales firſt collected Air under receivers; he found that mineral waters owed their ſpirit and briſkneſs to the Air united with them; he thought it was the ſame as atmoſpheric Air; he could not imagine that what ſhould be the ſource of briſkneſs in mineral waters, could be the ſame Mr. Boyle had found deſtructive to animals. Theſe were more particularly unfolded by Dr. Browning.

Dr. Black firſt pointed out the effects ariſing from depriving bodies of Air united with them, uſually called fixed Air, and how their cauſticity was deſtroyed by adding it to them. Since then Prieſtley, Cavendiſh, Scheele and Lavoiſier have clearly demonſtrated the exiſtence of many diſtinct and eminently elaſtic fluids.

Vital Air,

TERMED by Prieſtley, dephlogiſticated Air; by Lavoiſier, oxygenous Gas, from its being the Baſis of all Acids. The Air we breathe is formed of 28 parts of this Gas, with 72 parts of impure

pure Air, which being deſtructive to Life, is called azotic Gas.

When a Light is placed under a receiver, it will keep burning as long as there is any portion of pure Air; ſo metals, when calcined, are nothing more than an union with this Air, hence are ſaid to be oxydated; they then loſe their metallic ſplendor, their malleability, from being rendered ſoluble, become poiſonous; in conſequence of this union they have a proportional increaſe of weight. Light will diſengage this Air from many Acids, and from Vegetables. This laſt Mr. Cavendiſh attributes to the decompoſition of Water.

Vital Air is heavier than Atmoſpheric Air; a cubic foot of Atmoſpheric Air weighs 720 grains, of Vital Air 765.

The reſpiration of this Air is ſuppoſed by Dr. Crawford to be the ſource of animal heat; when Air has been reſpired, it becomes changed, being converted into fixed Air, and its capacity for Heat being then ſo much leſs, what was evolved in the change has been deemed a ſufficient ſource.

The theory of Dr. Crawford, reſpecting the capacities of bodies for Heat, ſhewn in many reſpects to be imperfect.

The medicinal properties of this Gas conſidered, Scheele, Chaptal, Cailliens, and Dr. Beddoes' opinions.

Azotic Gas

Lighter than oxygene Gas.

A cubical inch weighs 0.4444 of a grain: this Gas is the baſis of Nitrous Acid, hence by Dr. Pearſon has been termed Nitrigen Gas: if to 20½ parts of azot. 43½ parts of oxygen be added, 64 parts of nitrous Gas are formed; if to this we join 36 parts of oxygen, 100 parts of nitric Acid reſult from the combination; and when this laſt acid is united with Potaſh, Nitre or Salt Petre is formed.

Nitrous Air

Was firſt diſcovered by Dr. Hales, who in examining the Air that was diſengaged from the Walton Pyrites, by means of Spirit of Nitre, obſerved that when joined to common Air, an abſorption of part of the common Air enſued. Dr. Prieſtley extended theſe experiments, procuring the ſame Air from Aq. Fortis poured on any of the metals, as iron, copper, braſs, ſilver, &c. he found it produced no diminution in any part of the Airs but pure Air: he hence uſed it as a teſt for the purity of Air; the graduated inſtrument he uſed, he called an Eudiometer.

Nitrous Air being the ſame as nitric Acid, deprived of a portion of its oxygen, hence when the acid is poured on metals, theſe are calcined by the oxygen of the Acid, the remaining portion of the Acid becomes aeriform.

Carbonic Acid Gas

HAS been the longeſt known; Van Helmont called it Gas Sylveſtris, becauſe produced in vaſt quantities during the combuſtion of charcoal: it was formerly called fixed Air. It exiſts ready formed in chalk, marble, and all the calcareous ſtones neutralized by lime. From theſe it is eaſily diſengaged by ſulphuric Acid: this Gas is the heavieſt of all, a cubic foot weighing 807.34 grains. It is a compound reſulting from an union of Carbon and oxygen Gas; when charcoal and metallic oxyds are combined in proper proportions, the oxygen of the oxyd combines with the carbon forming this Gas, and the metal recovers its reguline ſtate; this has been elegantly analyſed by Mr. Smithſon Tennant, by mixing together ſome powdered marble ſlightly calcined, and ſome phoſphorous, in a glaſs tube well cloſed and luted, and then kept in a red heat for a few minutes when cool, a black powder is formed, which conſiſts of charcoal and phoſphat of lime.

This Gas unites with about its own bulk of Water, and acidulates it: this is the cauſe of briſkneſs in Pyrmont Waters; it ariſes in abundance from fermenting liquors. Air after it is reſpired is converted into this Gas; it is often found in mines and ſubterraneous places called choke damp. It was thought this was the Air in the celebrated Grotto del Cano: Spallanzani proves it to be azotic Gas.

It has the property of retarding putrefaction; whether this ariſes from the carbon might be a ſubject of enquiry?

Hydrogene Gas.

This Gas was uſually known by the name of inflammable Air; it is evolved from all putrid animal and vegetable matters; ſince the decompoſition of Water has been aſcertained, this fluid being found its principal ſource, hence has acquired the name of Hydrogene. It is the lighteſt of all the Gaſes, a cubic foot only weighing 41 grains: one hundred grains of water is found to be compoſed of 85 grains of oxygen Gas, and 15 grains of hydrogene Gas.

It is found in mines, and often produces the moſt dreadful effects; is called wild-fire. By being ſo ſpecifically light is the reaſon why balloons are ſo buoyed up.

This Gas is eaſily procured by diſſolving iron or zinc in diluted vitriolic Acid; the Water is decompoſed with rapidity: this Gas united with azot forms the volatile Alkali; theſe conſtitute the ammoniacal ſmell obſervable in putreſcent ſubſtances.

When medicinally uſed, by being mixed with about twelve times its bulk of common Air, alleviates irritations of the lungs.

With this Air Dillier exhibited his beautiful fire-works, varying its colours by different admixtures; thus inflammable Air of pit-coal, mixed with $\frac{1}{3}$ of the Air of the lungs, makes a blue flame with nitrous Air, green, &c.

Fluoric Acid.

Margraff diſcovered this Acid ready formed by nature in the fluoric ſpars, combined with calcareous earth, ſo as to form an inſoluble neutral ſalt: it is diſengaged by the ſulphureous Acid, as it diſſolves glaſs and ſiliceous ſubſtances, metallic veſſels muſt be employed. From this circumſtance it is that beautiful etchings may be

made

made on glaſs, as on copper, with the nitrous Acid; if we cauſe the fluoric Acid to paſs over into a recipient of water, it is condenſed and abſorbed by the Water.

By an attention to theſe elementary principles, the various changes which take place in animal and vegetable ſubſtances are eaſily explained: thus when an animal is deprived of Life, deprived of that active principle which preſerved theſe elements in their proper balance, the equilibrium is broke, the whole ſubſtance becomes perfectly analyſed, and nothing but a mould left behind; the hydrogene, one of the component parts of the circulating fluids, uniting with the azotic principle of the diſſolved animal fibre, from acquiring ſufficient caloric, to aſſume a gaſeous form, conſtitute the ammoniacal ſmell; the oxgen and carbon eſcape in the form of carbonic Acid, theſe four being the elementary parts of an animal.

Preſſure and Elaſticity of the Air.

THE Atmoſphere, principally formed of aerial particles, of Caloric, of Electricity and of Magnetiſm, being univerſally full, on this general plenum the phænomena of preſſure and of elaſticity depend.

If a pneumatic receiver could be formed of ſuch materials that neither Air, Fire, Electricity or Magnetiſm could permeate, then the proceſs of exhauſting the Air would be impracticable.

As we know of no body but what ſome of theſe ſubſtances will permeate, the phænomena which are produced by exhauſtion ariſe only from a change of place.

As Air cannot permeate a glaſs receiver, this elaſtic fluid may be drawn out; every exhauſtion of the Air from within when thrown into the general atmoſpheric maſs, muſt neceſſarily occupy a certain ſpace; as there is a plenum without, unleſs it can force by its preſſure an adequate bulk of Fire into the receiver, the reſiſtance to the exhauſtion would exceed every poſſible effort.

Every part of the receiver being permeable to Fire, an equal bulk of this principle immediately enters in.

The receiver is as full after the Air is withdrawn as before, of another principle.

A thermometer placed under a receiver from this circumſtance ſinks in proportion to the exhauſtion. As the receiver is ſurrounded by a fluid which cannot enter in, will be acted upon in proportion to its extent of ſurface; the reaction will be exactly equal to the force employed in the aerial exhauſtion.

This preſſure in an exhauſted receiver is as fifteen pounds on every ſquare inch.

The caloric within ſide the receiver is no ways a counteracting preſſure to the Air without; like water diffuſed in the vaſcular ramifications of ſponge, on the ſlighteſt preſſure paſſes through the receiver in every direction.

The Atmoſphere, formed by a combination of theſe different principles, acts as other fluids with reſpect to preſſure, in proportion to the perpendicular height,

As that portion of the Atmoſphere which is contiguous to the Earth is preſſed upon by that above, it will be in a comparative ſtate of condenſation; thus the denſity will diminiſh in the inverſe ratio of the columnar height.

What this ratio is, will be more particularly noticed when on Barometers,

Elaſticity of the Air.

Elasticity of the Air is not to be conſidered as any power peculiar to this fluid, or any kind of ſpring in its conſtituent particles, nor any ways different from that which is poſſeſſed by other fluids.

If at the bottom of a column of Mercury I place ſome Æther, the laſt rapidly riſes up; its ſpecific gravity, ſo much inferior to that of Mercury, yields to the preſſure all around, and riſes up with a velocity in the ratio of the difference of their denſities.

So Air, if in a different ſtate of denſity than the Atmoſphere, in the proceſs of equalization, evinces that power called by the term Elaſticity.

A ſmall quantity of Air included in a bladder cannot occupy a larger ſpace when ſurrounded by the Atmoſphere. When the denſity of the ſurrounding Atmoſphere is any ways diminiſhed, then the ingreſs of caloric into the Air in the bladder, takes place with that in the receiver, and thus becomes diſtended.

As Air of equal denſities undergo theſe changes equally, any portion of Air, however ſmall, will be equal to the atmoſpheric preſſure; it is preciſely in that ſtate in which it would be if unconfined.

Thus Air preſſing on a bladder tied over a receiver, or on the outer ſurface of a ſquare bottle, produces no effect, becauſe the Air within is an exact counterpoiſe to the Air without; abſtract this internal Air, and the preſſure of the outer Air will be ſoon evinced.

So if the outer Air be removed, the internal Air receiving additional caloric, will evince ſimilar power. The *Elaſticity* of Air is then equal to the preſſure,

Condenſation.

All bodies, of whatſoever kind, can undergo no change with reſpect to their bulk, without the medium of ſome other principle, as Caloric, Electricity, &c.

If one hundred cubic inches of Air be reduced to a ſpace of fifty inches, fifty cubic inches of Caloric, Electricity, &c. are diſengaged.

When Air is condenſed in a braſs ball, through the medium of a ſtrong glaſs tube, and a pair of ſenſible pith balls ſuſpended on the braſs, in the firſt proceſs of condenſation theſe diverge with poſitive Electricity,

The different gaſes give out different quantities, As the condenſation continues, caloric is given out, the ball becomes conſiderably heated. Theſe circumſtances demonſtrate, that in thus forcing the conſtituent particles of Air into a ſtate of greater approximation, the caloric and Electricity which are diſſeminated in the interſtices of theſe particles are forced out, and eaſily paſs through the ſubſtance of the braſs.

When this condenſed Air is ſet at liberty in reſuming its original ſtate, Electricity and Fire are rapidly abſorbed; pith balls diverge with negative Electricity, and a conſiderable degree of coldneſs is induced in all contiguous bodies.

In the fountain of Hiero, conſtructed on a large ſcale at the Chemnicenſian Mines in Hungary, the Air in a large veſſel compreſſed by a column of water 260 feet high; a ſtop cock is then opened, the Air iſſues out with great vehemence, becomes greatly expanded; ſo much cold is produced, that the moiſture from the ſtream of Air is precipitated in the form of ſnow, and ice is found adhering to the noſel of the cock.

In damp weather a common glaſs globe will bear the condenſation of three Atmoſpheres; when thus left on the return of a fine day generally breaks, not being able to bear the additional quantity of Caloric and Electricity which the Atmoſphere has acquired.

Air-Pump.

OTTO GUERICKE, mayor of Magdebourg, firſt exhauſted a receiver, placing it on water, and pumping the Air out. Mr. Boyle was the firſt who exhauſted it by means of a piſton moving in a barrel and a valve; there being only one barrel, the preſſure of the Atmoſphere was very great. Papin and Dr. Haukſbee removed this difficulty by adding another, ſo that the preſſures counteract each other.

Mr. Vream changed the alternate up and down motion into a circular one.

In theſe the valve covering one large hole, and the piſton not accurately covering the bottom, prevented any great exhauſtion. To remedy this, Mr. Smeeton, in 1752 made ſeven ſmall holes, inſtead of one large one, that the valve might be eaſier raiſed up, and cauſed the piſton to go down to the bottom.

Even in this the Air when rarefied to a certain extent, is incapable of raiſing the valve; one of this conſtruction rarely exhauſts more than 3 or 400 times. Mr. Haas, by a pedal contrivance to raiſe up the valve, was capable of exhauſting 1000 times.

The moſt perfect form is the Air-pump of Mr. Cuthbertſon, where inſtead of a valve he has a braſs cone with fifty or ſixty leathers, ſliding into a hollow cone; in this, exhauſtion has been carried to 2400 times.

To eſtimate the number of ſtrokes requiſite for any exhauſtion, the capacities of the piſton and receiver being known, the calculation is very eaſy.*

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* If the capacity of the barrel of an Air-pump is to the capacity of the receiver as a is to b, after every turn the quantity of Air extracted is to the quantity before as a is to $a+b$.

BAROMETER.

Some time after Torricellius had aſcertained that a column of Mercury thirty inches high was a counterpoiſe to the preſſure of the Atmoſphere, it was aſcertained by Deſcartes, Paſcal and Merſennus, that the Atmoſphere varied in its preſſure.

It was found that the column of Mercury was never leſs than twenty-eight inches, nor higher than thirty-one inches, marking its riſe or fall according to certain atmoſpheric changes, and hence adopted as a weather-glaſs.

This variation of three inches appearing too ſmall for minute diviſion, Deſcartes ſuggeſted a method which was executed by Huygens with two tubes, Mercury at the top, and Water at the bottom; as Water is ſo ſenſibly affected by temperature, this form was imperfect.

Cor. 1. Hence the quantities taken away at any number of ſucceſſive turns form a geometric ſeries, conſequently the whole can never be exhauſted.

In condenſation the ſame ſeries does not take place; after any number of ſucceſſive deſcents, the denſity is increaſed in arithmetic progreſſion.

Caſſini invented an horizontal Barometer; in this Mercury is very apt to be ſpilt.

1668, Dr. Hooke contrived a wheel Barometer; as the Pulley is moved by a ſtring which is influenced by moiſture, this is no ways correct.

The Torricellian will evince an alteration when Dr. Hooke is no ways changed, and when a Verniers ſcale is made uſe of, each inch becomes divided into 100 parts. The ſcale of variation being three inches, and each inch divided into ten parts, on this ſcale is fixed a moveable one of one inch long, and which inch is divided into nine parts; ſo that each diviſion of the moveable ſcale is one tenth of an inch more than the diviſion of the other.

Cauſe of Variation.

Varennius ſuppoſed exhalations differing in denſities. Dr. Halley attributed it to the variable winds. Leibnitz to water in ſtate of rain, not weighing with the Atmoſphere. De Luc attributed it to vapours. Dr. J. Hutton to ſudden changes of heat and cold. Dr. Darwin to ſome decompoſition of the Air. Dr. Bell to Electricity; which laſt ſeem the moſt probable, as the Mercury in the Barometer is higher in the morning

ing and evening than in the middle of the day. So Volta and Reid have obſerved the Atmoſphere is at theſe times more electrical.

The variation in the riſe of Mercury is the greateſt in thoſe latitudes where the greateſt changes in the ſtate of Electricity are alſo.

At St. Helena there is little or no variation; at Jamaica rarely more than $\frac{3}{10}$ of an inch, at Naples one inch, England 2 inches and a half, and Peterſburg 3 inches and one-third.

Height of the Atmoſphere.

If Air were of the ſame denſity at all altitudes, it would be eaſy to calculate the height, as Air is 11900 times heavier than Quickſilver, and 29 inches and a half of Quickſilver being at a mean a balance to the Air; from this the height of the Air would be about 5 miles and a half high. Air diminiſhes in its denſity in the inverſe ratio of the altitudes.

In 1648 Paſcal found the Mercury ſunk 3 inches and one-third upon the Puy de Domme being 3204 feet high. Mr. Caſwell found it ſink 3 inches and $\frac{8}{10}$ on Snowdon-hill, being 3720 feet high.*

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* Suppoſing the denſity is as the compreſſing force, its denſity at any height is eaſily determinable on the principle

SOUND.

GALILÆO, in endeavouring to aſcertain the velocity of Light, diſcovered that of Sound to be near 1100 feet in a ſecond of time; this was more accurately aſcertained by Dr. Halley, Newton, and Dr. Derham, to be 1142 feet in a ſecond: this motion they obſerved to be uniform, whether

of the logarithmic curve. The denſities of the Air will be denoted by the reſpective ordinates drawn perpendicular to the Aſymptot; if any portion of the Aſymptot be a given quantity, there is the ratio of the two ordinates, which intercept that portion, likewiſe given.

If the portions of the Aſymptot are in arithmetic proportion, then the reſpective ordinates are in geometric proportion. Upon this theory it appears that at five miles high, the Air is nearly 2.4 times rarer; at ten miles high, ſix times rarer; at fifty miles high, 6449 times rarer.

It has been obſerved by aſtronomers, by the duration of twilight, and the magnitude of the terreſtrial ſhadow in lunar eclipſes, that the effect of the Atmoſphere to reflect or intercept Light, extends to 50 miles.

Some Meteors have been obſerved very high; one in 1758 aſcertained to be 100 miles high, about a mile and a half in circumference, and exploded with a ſound like diſtant thunder. Either to communicate ſound, or for combuſtion, Air is requiſite; at this height would be infinitely too rare, if the above calculation ſhould be correct.

againſt the wind or not. Condamine, at Cayenne, found it to move 1175 feet.

Lord Bacon ſuppoſed Sound to be owing to ſome other principle than Air, as the Sound of a large bell did not in the leaſt agitate a flame placed near it. If a bell be agitated in an exhauſted receiver, no Sound is induced.

Sound is the action and re-action of the conſtituent particles of Air, without any material change of place; while wind is a change of place in a large volume of Air.

A ſhip when in motion does not interrupt any motions within, in whatever directions they are made, ſo the action and re-action of the conſtituent particles of Air are no ways checked by any motion of the maſs of Air where theſe motions are taking place.

The ſame as is produced in the curdly appearance of water in a drinking-glaſs, when rubbing the edge with the finger.

When the action and re-action are propagated through that moving maſs, they neceſſarily are checked in communicating to any maſs of Air from which they are receding; on this account the intenſity of Sound becomes diminiſhed. So on the contrary, in the direction of the wind, Sounds are heard more diſtant.

When a body is ſtruck, it gives forth a certain Sound, not a ſingle and ſolitary one, certain ſecondary and ſubordinate vibrations; if theſe bear no muſical proportion with the primary, a jarring diſſonance muſt be produced.

The art of arranging ſeveral ſounds in ſucceſſion, in a manner agreeable to the ear, is called melody. By pleaſing that organ by the union of ſeveral ſounds heard at one and the ſame time, is called harmony. Diſtance between one ſound and another is called an interval. A chord, compoſed of Sounds whoſe union or coaleſcence pleaſes the ear, is called a conſonance.

Thus the octave of a Sound is the moſt perfect conſonance, then the fifth, afterwards the third.

Diſſonance is a number of Sounds ſimultaneouſly produced, whoſe union is diſpleaſing to the ear; hence in muſical compoſitions, when theſe notes are made uſe of, they are announced to the ear by being found in a preceding chord, and by thus ſeeming to connect the two chords.*

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* Muſical characters were invented about 670 A. C. by Terpander; till the 13th century the notes were ſquare, on four lines, like thoſe of the Roman church, without any Marks for time: after St. Lewis' reign a fifth line was added. The Egyptians diſtinguiſhed the notes by the ſeven vowels. Voſſius tells us that Pope Gregory firſt made uſe of the firſt ſeven

If we ſuppoſe a ſtring divided into 1000 parts, the different lengths of the ſtring will be as follows:

Ut C uniſon, 1000 parts.
Re D ——— 888.9
Mi E ——— 800
Fa F ——— 750
Sol G ——— 666.6
La A ——— 600
Si B ——— 533.3
Ut C octave, 500

Why the octave ſhould be moſt in uniſon with the whole chord, then the fifth and third, was firſt

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ſeven letters of the alphabet. Guido Aretine, a Benedictine monk, in the 11th century, acquired great fame by expreſſing the muſical notes on a new ſcale, in order to facilitate the learning of this art: he is ſaid to have taken the words from a hymn of Paulus Diaconus, on John the Baptiſt.

Ut quam laxis *Re*ſonare fibris,
*Mi*ra geſtorum *Fa*muli tuorum,
*Sol*ve pollutis *La*biis reatum.
SANCTE JOHANNES.

The ſyllables uſed in ſolmiſation were originally theſe ſix. The Italians finding the ſyllable *Ut* rather difficult to pronounce, rejected it, and made uſe of *Do*, as is obſerved in the Armonia Gregoriana of Gerolamo Cantone; this is now rejected, and the ſolfaing by hexachords, as revived by Pepuſch, is generally adopted.

In the Sound of theſe words there is an evident difference, the intervals between *Ut* and *Re* and *Mi* being equal, are called tones, the others ſemitones.

mechanically explained by Galilæo, by comparing the vibrations of a muſical ſtring with thoſe of a pendulum.

A vibrating ſtring is to be conſidered as two pendulums vibrating in very ſmall arcs, a pendulum is fixed to one point, a muſical ſtring to two. A muſical ſtring is a double pendulum; hence one half of the chord will vibrate twice, while the whole chord vibrates once.

In every ſecond vibration of the ſhorter ſtring, there will be a coincidence with the vibration of the longer.

Thus the more frequent the concourſe or convibrations are, the greater the conſonance. If the length of the longer ſtring be 3, and the ſhorter 2, their vibrations are as two to three, and called a fifth.

Thus if different pendulums of the following lengths, which are in the ſame proportion as the ſubdiviſion of a monochord, be thrown into motion, thoſe which moſt frequently coincide in their vibrations produce a viſual conſonance, and are exactly the ſame as the notes.*

The

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* Suppoſing a pendulum one yard long; as the lengths of pendulums are as the ſquares of the times, the following will be the proportionate lengths.

C uniſon

The agreement between the ſenſations of hearing and ſeeing, is more beautifully illuſtrated by the coincidence between the diviſion of a monochord and the priſmatic colours.*

Sympathetic Sounds.

When one ſtring is ſtrung, another that is in concord with it will anſwer; if a diſcord, no motion will be produced.

This depends on the aerial undulations exciting correſponding vibrations in a ſimilar diſpoſed ſtring.

Hence it is requiſite that the ſtring ſhould be in concord with the other, in order that its vibrations ſhould have their courſe and recourſe ſimilar, conſonant to the aerial undulations.

C	uniſon	39.1	inches.
D	———	31	
E	———	27	
F	———	21.9	
G	———	17.37	
A	———	14	
B	———	12.3	
C	octave	9.7	

* Thus B correſponds to red, A to orange, G to yellow, F to green, E to blue, D to indigo, and C to violet.

When not ſo, a recourſe of the ſtring will not correſpond with the recourſe of the aerial undulation, and thus a motion of the ſtring cannot take place.

Echo.

When Sound is reflected by a body on which it infringes, is called an Echo.*.

Grounds ſurrounded by a wall, Sound returns to the ear many times, ſometimes ten or twelve. At Simonetto Kircher tells us of one the words were returned forty times.

Not only walls, but even thick woods and rocks, and even clouds. Some naval gentlemen have obſerved that when they enter an harbour with a high circular ſhore, the guns return a ſmarter Sound from the land, than from the ſhip's ſide.

Sometimes a ſecond Echo or a third is more powerful than the firſt, the ſuperior numbers of reflections more than compenſating for the decay of Sound; thus the celebrated Echo at the Lake of Killarney, in Kerry.

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* As the ſenſe of hearing in general is not capable of diſtinguiſhing more than 7 or 8 ſyllables in a ſecond, there muſt be the ſpace of $\frac{1142}{8} = 143$ feet between. Thus Woodſtock returns 17 ſyllables; hence 148 multiplied by 17, is 2431 feet.

Sound is reflected in angles equal to the incident ones. On this depends the theory of ſpeaking-trumpets: ſo alſo the whiſpering gallery at St. Paul's.

In courts of juſtice, as in the Houſe of Lords, to prevent any diſagreeable reflexions, the walls are adorned with tapeſtry.

Senſe of Hearing.

When the Air is thrown into a tremulous undulation, the Air is acted upon all around; that portion of Air which is contiguous to the external ear, will be reflected by the different depreſſions there are there, and accumulated in the meatus externus; the aerial tremors ſtrike upon the membrana tympani, which is provided with two muſcles, either to relax or to brace up the ear, according to the intenſity of the tremors; behind this membrane are placed four ſmall bones, which communicate the impreſſions to a membrane which covers an opening into the labyrinth. This labyrinth is filled with an aqueous fluid, to which the tremors are imparted; the labyrinth or bony canal, partaking of the motions, communicate the ſame to the auditory nerve which ſurrounds the canal externally.*

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* Nerves of the ear in fiſhes do not appear to paſs thro' theſe ſo as to get on the inſide, as is ſuppoſed the caſe in quadrupeds;

A canal called the euſtachian tube goes from the back part of the membrana tympani into the mouth, to allow of a free ingreſs and egreſs of Air, the ſame as the aperture on the ſide of a drum, elſe the vibrations of the membrana tympani would be impeded.

WINDS.

A Wind is a change of place of a large volume of Air.

Trade Winds.

If the earth were ſtationary, and the Sun always vertical to the Equator, there would only be a North Wind on the North ſide of the Equator, and a South Wind on the South ſide; the Air over the Equator being heated, becomes ſpecifically lighter; the heavier Air preſſing on each ſide, thus conſtitute the Winds.

The Air partakes of the diurnal motion of the Earth, from Weſt to Eaſt, as then the Air is approaching the Equator, it is approaching parallels of latitude which move with greater velocity, and

drupeds; I ſhould therefore very much ſuſpect that the lining of the tubes in the quadruped is not nerve, but a kind of internal perioſteum.

Hunter's Physiol. Essays.

hence will have an eaſterly direction. So on the South ſide will be a S. E. wind.*

Theſe Trade-winds extend to about 40 degrees on each ſide of the Equator.

Monſoons.

When from any peculiar ſituation of land in reſpect to ſea, the Tropics become moſt heated, theſe winds are produced ſo that floods of Air ruſh in from the North-Eaſt and South-Weſt; theſe being of different temperature, the Water is precipitated by their mixture. From April to October is a South-Weſt wind, from October to April a North-Eaſt wind.

Theſe Monſoons frequently occur in the Indian Ocean and the Bay of Bengal, and to theſe travellers attribute the riſe of the Nile.†

Eteſian

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[*] The Equator is not the concourſe of theſe Winds, but the northern parallel of 4 degrees, becauſe the Sun is longer on the North ſide of the Equator than on the South ſide. Thus in the Atlantic Ocean the S. E. Trade-wind extends as far as 3 degrees North, and the N. E. Trade-wind ceaſes at 5 degrees North; in this intermediate ſpace are found calms with rain, and irregular uncertain ſqualls; theſe limits varying in ſome reſpects according to the declination of the Sun.

[†] Theſe Monſoons deluge Nubia and Abyſſinia. The whirling of the aſcending Air was ſeen by Bruce in Abyſſinia;

Eteſian Winds

ARE Monſoons not having the eaſterly and weſterly directions, being reſtrained by chains of mountains which confine Egypt.

Cryptæ Æoliæ,

SPIRACULA or caverns where Wind is evolved. Schenchzer has deſcribed many. Sir William Hamilton mentions one in the Italian Iſle of Lacco, which acts as an ice-houſe.

General Winds.

WINDS in theſe latitudes the more regular are the N. E. and S. W. acquiring the eaſterly and weſterly direction from the cauſe aforementioned; the general winds are not reducible to any known

nia: every morning he ſays a ſmall cloud began to whirl round, and preſently after the whole heavens became covered with clouds. By this vortex of aſcending Air, the N. E. and S. E. winds flow in to ſupply the place of the aſcending column, became mixed more rapidly, and depoſited their rain in greater abundance. Mr. Volney has obſerved that the riſing of the Nile commences about the 19th of June, and that Abyſſinia and the adjacent parts of Africa are deluged with rain in May, June, and July.

law, many ariſing from local circumſtances. Thus the ſandy deſerts of Africa give a burning heat, whoſe effects are felt at Minorca and Gibraltar; from the ſame ſource originates that ſcorching wind which blows at Goree, on the River Senegal; ſo the deſtructive Wind on the Falkland Iſlands.

HYDROSTATICS,

In the original derivation of the word, means the relation between the weight of water and other bodies.

A Fluid may be defined a body whoſe conſtituent particles are ſpherical, and thus eaſily yield to any force impreſſed upon them. Owing to this property moſt of the principles of Hydroſtatics depend.

This is the reaſon why Fluids preſs equally in every direction, laterally as well as perpendicularly; the preſſure is no ways regulated by the quantity of Water, as the perpendicular height and their baſis reſpectively.

Thus one pint of Water may be made to preſs with a force equal to one hundred pints.

If a veſſel be wider at top than at bottom, the preſſure will only be as the width of the lower end multiplied into the height.

Thus the ſame quantity of Water, however ſmall, may produce a force equal to any aſſignable one, by increaſing the height and baſe upon which it preſſes.

Specific Gravity.

Specific Gravity of a Body is the weight of it, when the bulk is given and compared with another Body of the ſame magnitude; called *ſpecific* becauſe it is the comparative weight of different ſpecies of Bodies; thus a cubic inch of gold is 19 times heavier than a cubic inch of Water, hence it is ſaid to be as 19 to 1.

Rain Water is generally adopted as the criterion, as being eaſily procured and more uniformly the ſame, a cubical foot of which weighs 1000 oz. avoirdupois.

When a Solid is immerſed in a Fluid, it is preſſed by that Fluid on all ſides, and that preſſure increaſes in proportion to the height of the Fluid.

If a heavy Body, as lead, be immerſed in Water to ten or twelve times its own thickneſs below the ſurface of the Water, and the ſuperincumbent preſſure of the Water prevented, the lead will then remain ſuſpended.

If the ſuperincumbent preſſure of the Water be added, then the Body will ſink, only meeting with a reſiſtance of a weight of Water equal in bulk to the Body immerſed.

By this reſiſtance a heavy Body loſes ſo much of its weight, as equal to its own bulk of the Fluid in which it is immerſed.

This method is of admirable uſe in aſcertaining the purity of metals. Fine gold is 19.6 times heavier than Water, while ſilver is only 11 times heavier; if gold is adulterated with ſilver, the ſpecific gravity of the mixture will be leſs than gold and greater than ſilver, and thus the proportionate quantity of each may be eaſily aſcertained.*

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* Let the ſpecific Gravity of the gold be a, and that of ſilver b, ſince the weight of any Body is compounded of its magnitude and ſpecific Gravity; if the bulk of gold in the mixture be x, and that of ſilver y and c, the ſpecific gravity of the mixture, then $ax - cx = cy - by$, and conſequently $c - b : a - c :: x : y$.

Thus it will appear that by ſubtracting the loſs of gold from that of the compound, the remainder is the ratio of ſilver; the loſs of the compound from that of the ſilver is the ratio of the gold.

Suppoſing the ſpecific Gravity of the compound be 13.11, and the maſs weighs 258.8 grains.

Loſs in Water 258.8 grains of gold is 14.54 grains.
Ditto of ſilver 24.94
Ditto of the compound 19.74
Then $19.74 - 14.54 = 5.20$ ratio of ſilver.
And $24.94 - 19.74 = 5.20$ ratio of gold.

In this mixture the quantities are equal.

Thus Mercury in medicinal as well as philoſophical purpoſes, its purity is a conſiderable object; it is often adulterated with lead, which being ſpecifically lighter, is thus eaſily detected.

HYDROMETER

Is calculated to aſcertain with eaſe and expedition the ſpecific Gravity of Fluids.

Suppoſing an Hydrometer diſplaces a bulk of water equal to 1000 grains, and the ſtem is divided ſo that each diviſion correſponds to a grain of water; if, when placed in rain water it ſinks to the middle of the ſtem, and in common water it is one degree below this, and which will take place if there be the thouſandth part of difference in their ſpecific Gravities.

Proof ſpirits at the temperature of 55 degrees, weigh 7lb. 12 oz. per gallon, and rain water 7lb. 15 oz. ſo proof ſpirits is about $\frac{1}{40}$ part lighter than water.

An Hydrometer of this ſize would require 25 grains more to ſink it in water, than to the ſame height in proof ſpirits.

Theſe Fluids not only vary in their ſpecific Gravities according to the temperature, but the bulk of the mixture is ſomewhat leſs than the ſum of the two bulks before the mixture.

Sir Charles Blagden has given a table of the real ſpecific Gravities of every 20th addition of Water to Alkohol, from 30 degrees to 100 degrees temperature.*

HYDRAULICS.

Pumps were in uſe previous to the Chriſtian æra, ſaid to be invented by Cteſebes, an Athenian: the principles on which they acted were not known till the time of Galilæo.

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* Monſ. Pouget found Alkohol at 15 deg. temperature to Water as .8199 to 1, he found in ten mixtures in proportions as below, the diminutions of bulk were as follows:

Water.	Spirit of Wine.	Diminution of Bulk.
1 part	9 parts	0.0109
2	8	0.0187
3	7	0.0242
4	6	0.0268
5	5	0.0288
6	4	0.0266
7	3	0.0207
8	2	0.0123
9	1	0.0044

So that the greateſt diminution takes place when the quantities of Water and Spirits are equal.

Thirty-three feet of water being a counterpoiſe to the preſſure of the Atmoſphere, whenever a column is exhauſted of Air, the preſſure of the outer Air will force the Water up 33 feet; at any diſtance lower than this, a valve is placed to admit the Water to riſe up and to prevent its return.

The force required to work a Pump, is as the altitude of the Water to be raiſed, and as the ſquare of the diameter in that part where the piſton works.

Forcing Pump.

In this there is no valve in the piſton; after the Water is raiſed into the barrel, it is forced up into a reſervoir. In this the ſtream of Water is alternate; to render it uniform, an air veſſel muſt be made uſe of.

Diving Bells,

As conſtructed by Borellus, Halley, Triedwald, &c. formed like a bell; Dr. Halley in one deſcended 52 feet, and remained an hour and a half. Mr. Smeaton's Diving Cheſt is the beſt conſtructed, and uſed with great ſucceſs at

Ramſgate; the Air ſupplied by a forcing Air Pump.*

SYPHON.
FOUNTAIN.
JETS D'EAU.

SPRINGS, RIVERS, &c.

IT was imagined generally by ancient and modern philoſophers, that Springs originated from Rain and Clouds attracted by the mountains, theſe formed Springs; Springs, Rivers; and Rivers the Ocean; from theſe, Clouds were again formed by evaporation. Monſ. Gualtieri ſhewed that the Waters diſcharged into the Sea by the Rivers of Italy, were to the Rain which fell as 55 to 27; De la Hire, that the Rain of 18 years did not penetrate 8 feet of earth; and Dr. Hales demonſtrated that the Rains did not ſuffice for vegetation.

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* In 1774, at Plymouth, Mr. Day engaged for a wager, in a Diving Boat of his own conſtruction, to remain twelve hours, 100 feet deep, periſhed in the attempt.

In 1783, Mr. Spalding went down with one of his aſſiſtants, to view the wreck of the Imperial Eaſt Indiaman, at the Kiſh Bank, Ireland; they remained about an hour, had two barrels of Air ſent, on the ſignals not being repeated, were drawn up and both found dead.

At a certain depth Water is found, theſe effuſions ſeem to be ſupplied from reſervoirs ſtill deeper, they by their turns fed by larger and deeper.

The Earth may be regarded as a Globe having internally a great number of vaſcular ramifications through which Water flows, thrown into motion by the motions of the Earth, and Rivers deſcend in the declivities on the ſurface.

Monſ. Buache conjectures that there is an uninterrupted ſeries of mountains and high grounds, which divide the Earth into four declivities. Theſe chains of mountains forming Belts; thus the Alpine Belt extends through the 45th, 46th, and 47th degrees of N. Lat. paſſing through Switzerland, Tyrol, Savoy, Saltſburg, Auſtria, Moravia, Bohemia, Poland, Pruſſia, &c.

This Belt originally went round the Globe, by extraordinary revolutions has been divided and thus ſeparated the old and new continent, in paſſing under the Sea, the elevated peaks form that Archipelago of Iſlands which derives its name from the unfortunate Bhering, again riſe and enter North America, running in the ſame parallel, and giving riſe to the Ohio, St. Lawrence, Miſiſſipi, till they are loſt in Canada.

Thus Mungo Parke obſerved a ſimilar Belt in Africa, between 10 and 11 degrees North, and 2 and 10 degrees Weſt Long. from Greenwich, in the higheſt part of which chain was ſituated the ſource of the Gambia.

Owing to theſe irregularities of the ſurface of the Earth, Currents and Streams proportionably take place: thus the greateſt depth of the Wells at Schemnitz is 200 fathoms, yet it appears from the barometrical calculation of Noda, that the greateſt depth of theſe mines is 286 fathoms higher than the city of Vienna.

In digging into the Earth, according as the ſurface is more or leſs elevated, theſe veſſels are more or leſs deep, when one is cut into, conſtitutes what is called a Spring.

Sometimes this opening may be in the loweſt part of the veſſel, the Water being prevented finding its own level, in conſequence of the reſiſtance of the ſuperincumbent Earth; when this is removed, riſes conſiderably up: thus the Well at Sheerneſs the Water roſe 300 feet above its ſurface. At Connecticut, in America, a Well was dug 70 feet before Water was found; on removing a large ſtone, the then uncontrouled Spring guſhed forwards, run over, and ever ſince has formed a Brook.

Upon theſe principles may be eaſily explained why a warm mineral Spring may be contiguous to a common one.

Under Currents.

If one of theſe aqueous veſſels ſhould open in a River, in a direction oppoſite to the ſtream, it will conſtitute an Under Current.

Dr. Halley obſerved this in the Straits of Gibraltar; Triedwald has particularized the ſame in the Baltic, and Smeaton the ſame at Long Reach,

In the Current of the Baltic a veſſel is carried with great rapidity; to check this, a flat board is ſunk about 30 fathoms, the contrary direction of the Under Current ſtops their progreſs.

HYGROMETER

Is an inſtrument intended to diſcover the moiſture contained in the Atmoſphere.

All ſubſtances which are twiſted are contracted by moiſture, while other ſubſtances are lengthened. Thus wood expands by moiſture; ropes, catgut, beard of a wild oat, &c. contract. Mr. De Luc found that whalebone and box cut acroſs their fibres increaſed nearly in proportion to the quantity of moiſture; whalebone he preferred, as it uniformly returned to the ſame point, and its expanſion greater, nearly one eighth of its length.

THERMOMETERS.

An inſtrument contrived for meaſuring the relative degrees of heat in Bodies.

Its invention is attributed to ſeveral perſons, Sanctorio, Galilæo, Father Paul, &c. Drebbel introduced it into England.

The firſt were only filled with Air, about 2 feet long, and a ſmall quantity of coloured liquor in the tube. Air, although very ſenſible, yet being influenced by other cauſes than by temperature, on this account is imperfect. The Florentine academicians filled them with Spirits. Dr. Hooke introduced them into England. As ſpirits of wine will not aſcertain the higher degrees of Heat, Newton adopted linſeed oil in a tube 3 feet long, and half an inch wide, and the ball two inches; this being inconvenient from its length, and inaccurate from the oil adhering to the ſides of the tube, induced Farenheit to fill his with Mercury, and which at the ſame time was alſo done by Prims in England. When Maupertuis and the French philoſophers went to the polar region, the Spirit Thermometers burſt, the mercurial ones remained perfect; at the ſame time Boerhaave adopting Farenheit's, render it general.

All Fluids, excepting Air, are inferior to Mercury in ſenſibility.

Graduation of the Thermometer.

At firſt there were no general ſtandard; the Florentines adjuſted to the greateſt ſunſhine Heats of their country, which were neceſſarily vague and uncertain. Mr. Boyle recommended the freezing of the eſſential Oil of Aniſeed, or the congelation of diſtilled Water. Dr. Halley preferred taking as a ſtandard places deep under ground, as Mr. Boyle had obſerved that 130 feet deep the Thermometer was uniformly the ſame: De la Hire and Miraldi found the ſame under the Royal Obſervatory at Paris, and thus graduated theirs. Afterwards Dr. Halley recommended the heat of boiling water, which Newton and Amontons adopted; Farenheit firſt obſerved that this varies as the preſſure of the Atmoſphere, hence Thermometers ſhould be graduated when the Barometer is at 29 and ½. Mr. Cavendiſh, obſerving a librating motion in the boiling heat, recommends the ſteam as more correct.

The Graduation which is made uſe of in England and Holland, is that of Farenheit's; in the forming of which he made uſe of a large Thermometer, ſuppoſing the greateſt poſſible degree of cold was that produced by a mixture of Snow or beaten Ice and Sal Ammoniac, he fixed this point at Zero, the Mercury in the tube weighed 11124 grains; when placed in water beginning to freeze, the Mercury roſe up 32 grains, which he marked as his freezing point; when placed in boiling water, it roſe up 212 grains, and which characteriſed that degree.

To have a very ſenſible Thermometer, the bore ſhould be very ſmall, and the ball large, if inſtead of being round was flat, the Mercury would expoſe a larger ſurface,

To aſcertain the higher degrees of Heat, Mr, Wedgewood's ſquare pieces of clay, which contract, by great intenſities of Heat.*

Degrees of Cold.

BOERHAAVE imagined that the Air was never colder than 32 degrees; and when Farenheit had by

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* Mr. Wedgewood divides his ſcale into 160 degrees, the firſt degree that at which clay firſt begins to contract, the loweſt degree of his Thermometer equal to 1077 of Farenheit; he found the following to be melted at the degrees here marked.

Nankeen Porcelain....	21877 Degrees Farenheit,
Pig Iron for caſting...	20577
Plate Glaſs...........	17197
Welding Heat of Iron.	13427
Gold melts............	5237
Silver melts...........	4717
Braſs melts...........	3807

by a mixture of pounded Ice and Aqua Fortis produced a degree of cold of 72 degrees below the freezing point; a cold ſays Boerhaave that muſt prove deſtructive to all animated nature.

At Peterſburg, in the year 1759, the Thermometer was 74 degrees below the freezing point. Pallas obſerved at 129 deg. when Gmelinus publiſhed an obſervation of its ſinking to 137, it was doubled in 1760: the ſame was obſerved in Sweden.

Artificial Cold.

Professor Braun, in December 1759, reſpecting Farenheit's experiments for want of Ice and Snow, and to his great ſurpriſe ſunk down to 184 degrees below freezing, and the Quickſilver rendered ſolid. In 1763 Pallas had $\frac{1}{4}$ lb. of Quickſilver froze by the natural Cold.

The Southern Latitudes are much colder than the Northern, which ſeem to ariſe from the different diſtances of the Earth in the Winter and Summer, as the Earth is three millions of miles nearer the Sun in our Winter than in our Summer; although the rays of Light are more oblique, yet we are one thirty-ſecondth part nearer the Sun. In the Southern Latitudes it is the reverſe: in their Winter the Earth is alſo three millions of miles more remote; ſo that they have an increaſed diſtance added to the obliquity of the Solar rays.

ASTRO-

ASTRONOMY.

THAT branch of natural knowledge which relates to appearances in the Heavens and the cauſes of them, is termed Aſtronomy.

A ſpectator viewing the Heavens, conceives himſelf ſituated in the centre of a Sphere, upon the concave ſurface of which, all the heavenly Bodies are diſpoſed.

The ſyſtem at preſent adopted is that of the moſt ancient; Pythagoras derived it from his intercourſe with the Chaldeans, and this continued till the period of Ptolemy, who lived about a century after our Saviour.

The Ptolemaic theory prevailed till the 15th century, when Copernicus revived the Pythagorean Syſtem.

About 50 years after another ſyſtem aroſe, created by Tycho Brahe, which has been adopted by very few.

The Pythagorean or Copernican Syſtem.

THE Sun in the centre, round which all the planetary Bodies revolve, and in the following order; Mercury, Venus, the Earth and Moon revolving round the Earth, Mars, Jupiter, Saturn, and Georgium Sidus.

This order coincides with the different appearances.*

Ptolemaic Syſtem

SUPPOSES the Earth in the centre, the Moon, Mercury, Venus, Sun, Mars, Jupiter and Saturn moving round.

Syſtem of Tycho Brahe.

THE Earth in the centre, the Sun and Planets revolving round once in 24 hours.

Orbits of the Planets.

TILL the period of Kepler, 1609, the Orbits of the heavenly Bodies were believed to be circular; he firſt publiſhed his Commentary on the Motion of Mars, and ſhewed that the Planet deſcribed an Ellipſis about the Sun, and that the Sun was placed in the lowermoſt focus; he conjectured this might be the caſe with every other.*

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* Venus and Mercury ſometimes appear ſtationary, at other times retrograde in their motions, while if the Earth were in the centre, they ought to be obſerved uniformly moving round; alſo Venus and Mars appear ſix or ſeven times larger at one time than at another, which demonſtrate that in their orbitary revolutions there muſt be very great difference in their diſtances from the Earth.

Sun†

In diameter is 893522 miles, and is 1434400 times greater than the Earth. The Sun has two motions, one round its Axis in 25 days ſix hours, and an irregular orbitary one round the common Centre of Gravity. As the Centre of Gravity can never be farther removed from the Sun's Centre than its circumference, the orbitary revolution is comparatively ſo trivial, that the Centre of the Sun is generally calculated as the Centre of Gravity of the ſolar ſyſtem.

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* Kepler whimſically imagined that the Sun was alive, and that the revolution round its Axis was the action of its Soul; the eccentricity of the Orbits of the Planets, he imagined the Bodies of the Planets were compoſed of fibres in form of bearded arrows, which lay all the ſame way, flattened when their points were offered to the Sun on one ſide, which ſtood erected when offered to it on the other; ſo that when that ſide was expoſed to the Sun where theſe barbs retreated and flattened, this mark of reſpect was deemed friendly: hence the Sun attracted it nearer to itſelf, when they were reverſe and in an offenſive, hoſtile motion, was ſuppoſed inimical and repelled by the Sun.

† Called Sol by the ancients, becauſe as Macrobius ſays, he appears *ſolus* or alone.

When the phaſe of the Sun is examined through a teleſcope, a number of ſpots is obſerved of various ſizes; by daily obſervation theſe gradually change their apparent ſituation, and return again into their ſame place at the expiration of 25 days, ſix hours: owing to this the revolution round its Axis is aſcertained.

Theſe ſpots are ſome of them of an amazing ſize, equal in magnitude to the ſurface of the Earth. Rev. Mr. Wollaſton of Cambridge ſays, with a twelve inch reflector he ſaw a ſpot burſt to pieces, and appeared like a piece of ice broke, radiating in various directions.

What theſe ſpots are, is a ſubject much diſputed. Scheiner thinks they are volcanoes not appearing ſo luminous as the Sun, have that dark look: hence he calls them Faculæ or little Torches. Dr. Wilſon fancies they are excavations in the Sun, as he ſuppoſes the Sun is in a ſtate of combuſtion on its ſurface: ſome of them are found to be 4000 miles wide, and as many deep; theſe are obſerved to vary in their ſize, and ſometimes entirely vaniſh, while new ones are produced. Hevelius obſerved one which appeared and vaniſhed in 16 or 17 hours, and none of them have been obſerved to continue longer unchanged than 70 days.

As it is now generally believed that the Sun is the fountain of Light, but not of Heat, Dr. Herſchel thinks it may be inhabited.

Mercury

In diameter is 3261 miles, 37 millions of miles diſtant from the Sun, and about $\frac{1}{14}$ as large as our Earth; he moves round the Sun in 88 days, a velocity equal to 110680 miles every hour.

Mercury, like all other Planets deriving all its Light from the Sun, will be ſeen by the inhabitants of the Earth undergoing all the changes of the Moon; this was firſt obſerved by Galilæo, who firſt applied a teleſcope to the Heavens.

Mercury never appearing remote from the Sun, it is but rarely he can be ſeen; in general he appears within a quarter of an hour of the Sun, ſo immerged in its luminous rays, that no obſervations have been made on its Body, in order to aſcertain its revolutions round its Axis.

Venus.

In diameter is 7699 miles, and 69 millions of miles diſtant from the Sun, revolves round this luminary in 224 days, and round its Axis in 23 hours, 22 minutes, in ſize is equal to our Earth;

its orbitary velocity is 80955 miles per hour. Venus being more remote from the Sun, is more eaſily examined.

Galilæo firſt obſerved that when ſhe was perfectly round and full ſhe appeared ſmall, and larger as ſhe became gibbous.*

Caſſini, in 1666, firſt obſerved a bright ſpot in Venus, and concluded that ſhe revolved round her Axis in little leſs than one of our days.

In 1726, Signior Blanchini obſerved many ſpots in Venus.

Mr. Schroeter, of Bremen, thinks Venus has an Atmoſphere; when obſerving Venus in her Creſcent, the outer Limb is more luminous than the inner ragged one, the Light fading away, as is obſerved in the gradual diminution of Light on Atmoſphere; this muſt be more ſenſible in the middle than at the Cuſps.

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* The luſtre of Venus being ſometimes ſo great as to be ſeen in the day-time, gave occaſion to Dr. Halley to enquire into the cauſe: he propoſes this problem, " In which part of her Orbit, with reſpect to the Earth, is the illuminated portion of Venus' Diſk, turned towards the Earth, the greateſt that it can be"?

He found this to be when that Planet is about 40 deg. diſtant from the Sun, and when little more than one quarter of her viſible Diſk is luminous, and ſhe reſembles the Moon about five days old, in every eight years ſhe returns to the like poſition again; ſo that ſhe may be ſeen the ſame day of the month, and hours, nearly in the ſame place.

When Venus departs out of the Sun's Rays, on the weſtern ſide, we ſee her in the morning juſt before day-break, ſhe is then called the Morning Star, at this time appears like a fine thin creſcent; juſt a verge of ſilver light is ſeen on her edge.

Of the ſuperior Planets.

MERCURY and Venus are termed the inferior Planets, thoſe which move in Orbits circumſcribing that of the Earth, are termed ſuperior. Theſe exhibit phenomena conſiderably different, in their motions they always appear retrograde when in oppoſition, and direct when in conjunction.

The elongation of the inferior Planets is leſs than 90 degrees, ſo ſeem conſtantly to attend the Sun, the ſuperior are ſometimes 180 degrees.

The ſuperior Planets are never ſeen croſſing the Sun's Diſk, as in their revolutions they are ſometimes nearer to, and ſometimes further from the Earth, and their apparent diameter is found to vary according to the difference in their diſtance.

Mars

Is 5312 miles in diameter, 146 millions of miles from the Sun, goes round the Sun in 686

days,

days, revolves round its Axis in 24 hours, 39 minutes, is $\frac{3}{16}$ of the ſize of the Earth, and moves in its orbit with a velocity of 55783 miles in an hour.

Dr. Hooke firſt obſerved a ſpot in Mars, by which its revolution round its Axis was aſcertained by Caſſini. In 1704 Maraldi obſerved many ſpots.

Mars, when in oppoſition to the Sun, is five times nearer to us than when in conjunction.*

Mars appears to have a conſiderable Atmoſphere. Caſſini obſerved a Star in the water of Aquarius, at a diſtance from the Diſk of Mars became ſo faint before its occultation, that it could not be ſeen with the naked Eye: Roemer obſerved the ſame at Paris. Alſo Dr. Herſchel has often perceived occaſional changes of partial bright Belts, which ſeem to ariſe from the variable diſpoſition of an Atmoſphere.

Jupiter

Is 90,255 miles in diameter, 499 millions of miles from the Sun, revolves once round the Sun in 11 years and 314 days, and round its Axis in 9 hours 56 minutes; in magnitude is 1479 greater than the Earth, and moves in its orbit with a velocity of 30,193 miles in an hour.*

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* As the Earth is at a mean 96 millions of miles from the Sun, then Mars at its neareſt diſtance will be 50 millions of miles from the Earth; when at its greateſt diſtance, will then be 242 millions of miles.

This Planet appears with Bands or Belts, which were firſt obſerved by Gaſſendus; Caſſini, while viewing Jupiter, ſaw five Belts, and in the courſe of an hour two diſappeared. What theſe are, and why when obſerved always form parallel ſtrata, are circumſtances not yet accounted for.

Saturn

Is 80012 miles in diameter, 916 millions of miles diſtant from the Sun, revolves round the Sun in 29 years 167 days, and round its Axis in 10 hours 12 minutes; its magnitude is 1030 greater than the Earth, and moves in its orbit with a velocity of 22,298 miles per hour.

Galilæo thought it a tricorporate Body,† ſuppoſing it to be compoſed of three globes; 50 years afterwards Huygens aſcertained its annular ſtate. What Galilæo took for two Stars, were parts of a Ring, which ſingular and curious appendage encompaſſes the Body of this Planet without touching

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[*] This great velocity of Jupiter renders his figure ſpheroidal; his equatorial diameter to the Polar one is as 13 to 12.

[†] Altiſſimam planetam tergeſimam obſervavi.

ing it; the ſpace between the Ring and Globe is about 21,000 miles, and the breadth of the Ring is nearly the ſame. Dr. Herſchel has diſcovered another Ring, concentric to this, and much larger.

What theſe Rings are intended for is not known; they are inclined to the plane of the ecliptic in an angle of about 30 degrees, hence well calculated to reflect Light to the polar regions of Saturn.

Georgium Sidus

WAS not known as a Planet till Dr. Herſchel's obſervations were engaged to it from the ſteadineſs of its Light; in applying higher magnifying powers to his teleſcope he found the diameter increaſed; in two days its place in the Heavens was changed: to ſee it thus, the magnifying power ought to be more than 300 times.

This was diſcovered in 1781; in diameter is 34,217 miles, diſtant from the Sun 1832 millions of miles, performs its revolution in 80 years; in magnitude is 81 $\frac{1}{16}$ larger than the Earth, and moves with a velocity of 16,411 miles per hour.

The mean diſtance of all the Planets is generally more conciſely expreſſed by aſtronomers; ſuppoſing the diſtance of the Earth from the Sun be divided into ten parts, Mercury may then be eſtimated at 4, Venus at 7, Mars at 15, Jupiter 52, Saturn 95, and the Georgium Sidus 190 parts.

Earth

Is ſituated in the Solar ſyſtem, between Venus and Mars; its mean diſtance from the Sun is 96 millions of miles, its diameter 7920 miles; moves round the Sun once in 365 days, 5 hours, 48 minutes, and with a velocity in its Orbit of 68,856 miles per hour.

Who it was found out the Earth's ſpherical figure, lies hid in the dark ruins of antiquity; certainly the opinion is very ancient, for when Babylon was taken by Alexander, Eclipſes were there found calculated.* Thales in the Ionic ſchool collected all the relations given by travellers, brought all theſe particular Lights upon a ſphere, and produced in Greece the firſt terreſtrial Globe.

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* When any Body in all ſituations and under all circumſtances projects a circular ſhadow, that Body muſt be a Globe. Thus the ſhadow of the Earth, whether projected Eaſt or Weſt, North or South, in eclipſing the Moon, is always circular.

The Earth loſes very little of its ſphericity by mountains and valleys. Mont Blanc, an enormous maſs of granite in the centre of the Alps, meaſures 2750 fathoms; the Cordilliers 3030 fathoms, Quito 1707, El Coraſin 2470, Ek Atlas 2730, all parts of the Cordilliers or Andes. Peak of Teneriffe 1934 fathoms, Mount Ætna 1672, Mounts Olympus, Taurus, and Cenis 1460 fathoms, &c.

Secondary Planets

ARE thoſe which attend the primary Planets; Mercury and Venus have none, the Earth is attended by one Moon or Satellite, which is ſituated about 240,000 miles from the Earth, and moves round the Earth in 27 days, 7 hours, 43 minutes, which is called the periodic month; in this time ſhe has performed one entire revolution about the Earth, from any point in the Zodiac to the ſame again.

The Moon's motion conſidered with relation to the Sun, is the exceſs of the velocity of the Moon's motion above the velocity of the Sun's apparent motion; this exceſs varies: the mean motion of the Moon from the Sun is 12 degrees, 11 minutes, 26 ſeconds in a day, which carries the Moon from one conjunction to another in 29 days, 12 hours, 44 minutes, 3 ſeconds. This is called a ſynodical month or lunation.

The Moon turns about its own Axis in the ſame time it moves round the Earth; it is on this account that ſhe always preſents nearly the ſame face to us: by this motion round her Axis ſhe turns juſt ſo much of her ſurface conſtantly towards us, as by her motion about the Earth would be turned from us.*

The Moon, when viewed through a teleſcope, does not appear ſmooth like a ſpeculum, rough and uneven with mountains, caverns and valleys. Theſe irregularities are more particularly obſerved in the creſcent ſtate.

Whether there is any Atmoſphere about the Moon, is not yet known, ſhe always appears clear when our Atmoſphere is; yet Feuillée and De la Hire ſays, that a Star paſſing behind the Moon has been refracted; this by others is denied, yet ſome have obſerved the Sun to have a trembling kind of motion juſt before an Eclipſe, and to appear oval.

In 1787 Dr. Herſchel obſerved ſome luminous ſpots in the dark part of the Moon, occaſionally very vivid; he deems them volcanoes. Don Ulloa, when in South America, had obſerved a ſimilar ſpot at the time of an Eclipſe; he thought there was a hole through the Moon, which let the Light paſs through.

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* The motion about the Axis is equable and uniform, but that about the Earth is irregular, from the Orbit being elliptical, conſequently the ſame preciſe part is not actually preſented towards the Earth; a little ſegment on the Eaſtern and Weſtern Limb appear and diſappear. This is called the Moon's *Libration.*

Different Phaſes of the Moon,

As the Moon goes round the Earth, more or leſs of her enlightened half will be preſented towards us, ſometimes ſhe looks full upon us, ſometimes only half her enlightened face; ſoon ſhe appears as a radiant Creſcent, and at another time inviſible.

Moon revolves round the Earth from Weſt to Eaſt, when in oppoſition to the Sun we ſee it quite full, when in conjunction is generally inviſible a day or two; then a line appears in a creſcent form, increaſing, till at the firſt quarter ſhe appears in the form of a ſemicircle.

The next Planet which has Moons is Jupiter, he has four of them; theſe were diſcovered by Galilæo, who called them the Medicæan Stars; of theſe he only ſaw three, the fourth was diſcovered by Huygens.

The application to navigation was ſuggeſted by Galilæo, and firſt put into practice by the aſtronomers Condamine, Bougouer, Don Ulloa, &c. By theſe Roemer determined the velocity of Light.

Satellites of Saturn.

Huygens diſcovered the fourth Satellite: Caſſini 16 years after diſcovered four, being the 3d, 5th, 6th and 7th. In 1789, Dr. Herſchel diſcovered two nearer the Body of Saturn, viz. the 1ſt and 2d. Theſe are ſo minute as not to be ſeen unleſs the Air is exceeding clear,

Satellites of Georgium Sidus.

In 1787, January 11, Dr. Herſchel diſcovered two Moons, &c.

All theſe Moons appear to anſwer the important purpoſe of reflecting Light to their reſpective primaries, and if they reſemble ours; this ſeems to be the principal purpoſe of their creation, they ſeem not to be calculated for Beings like unto ourſelves.

Seaſons.

The Orbit of the Earth being elliptical, and the Earth's Axis being inclined to the plane of this Orbit, in an angle of 23 degrees, 30 minutes, to theſe the change of Seaſons is owing.

As far as this angle extends, the inhabitants of every part of this circle will ſucceſſively have the Sun vertical to them.

The Summer is nearly eight days longer than the Winter; as the Earth is farther removed from the Sun in Summer than in Winter, the velocity with which it moves through the Orbit is diminiſhed: the Earth as well as all the Planets, deſcribes equal areas in equal times.

Diviſion of Time.

THERE is no correct account reſpecting the ancient diviſion of Time; it is ſaid by ſome the Egyptian years were our months; the Arcadians divided their year into three months, the Romans into ten.*

The

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* Romulus made this diviſion, viz. March, April, May, June, Quintilis, Sextilis, September, October, November, and December; Quintilis and Sextilis were afterwards changed into July and Auguſt, in honour of the two Cæſars. Numa added January and February. Even this increaſe divided the year into only 354 days, the eleven days he doubled every ſecond year and made another month, called Mercidonius: this intercalation was left to the prieſts, who frequently omitted it; thus the feaſts fell on different times. Julius Cæſar to rectify this, made one year of 15 months, he then added the 11 days to the 354, making the year 365 days, equal to

The Time meaſured by the Sun's apparent revolution from any fixed ſtar to the ſame fixed ſtar again, is 365 days, 6 hours, 9 ſeconds, 14 thirds.

The Time meaſured by the Sun's revolution in the Ecliptic, from any Equinox or Solſtice to the ſame again, is 365 days, 5 hours, 48 ſeconds.

the courſe of the Sun within 6 hours; theſe hours were left alone till they made one day; every 4th year he placed this day, and in that part of the calendar where the intercalary month uſed to be put, viz. five days before the end of February, and ſixth of the Calends of March, for this year the ſupernumerary day was called Biſſextus; this is called the Julian Period, and which would have been correct, had the Sun apparently finiſhed its revolution in 365 days, 6 hours. The interval of Time from the Sun's leaving the firſt point of Aries, till his return to it, is 365 days, 5 hours, 48 minutes, and 48 ſeconds, being 11 minutes and 12 ſeconds leſs than the Julian computation: this in a century makes a difference of 18 hours, 24 ſeconds. At the time of the Council of Nice, in 1582, it was found that the Sun had entered the equinoctial circle on the 11th of March inſtead of the 21ſt. Pope Gregory XIII. took theſe 10 days, ordered that the 11th ſhould be deemed the 21ſt. This was called New Stile, and immediately adopted in every Roman Catholic country, not adopted in England till the middle of this century: to prevent this difference, he ordered that every 100th year ſhould be a common year, not a Leap Year. This will lead into an error on the contrary ſide; every century the difference does not amount to one day, to render it more equal every 400th year ſhould be Leap Year.

The former is called the Sidereal Year, the latter the Tropical.

The Lunar Year, or twelve Synodical Months, conſiſt of 354 days, 8 hours, 48 ſeconds, and which ſeems to have been the year the Romans at firſt adopted.

A Week.

THE firſt mention of a Week is in Geneſis, derived from the Moſaic account of the Creation. Joſephus obſerves that in all cities of Greeks or Barbarians, the ſeventh day is obſerved. Dion Caſſius, the hiſtorian who wrote in A, D. 210, ſays, the referring of days to the ſeven Planets was an invention of the Egyptians, in the order of the vulgar ſyſtem, viz. of Ptolemy's. Suppoſing the Earth in the centre, Saturn to govern the firſt hour of Saturday, counting according to the order of the Planets, the twenty-fourth hour will fall to Mars, the firſt hour of the next day will belong to the Sun, who therefore will govern that hour, and give the name to the day, &c.

Eclipſes of the Sun and Moon.

As all the Planets derive their Light from the Sun, whenever one Planet is interpoſed between the Sun and another Planet, a proportionate deprivation of Light will take place.

If the orbit of the Moon had not been inclined to the plane of the Ecliptic, there would then have been two Eclipſes every lunation; as the Orbit is inclined in an angle of 5 degrees, there can only be an Eclipſe when the Sun, Moon, and Earth are in a right line. The Moon's Orbit, if produced, would cut the Ecliptic in two points, called her Nodes, or places of interſection, ſo that one half of the Moon's Orbit will be above the Ecliptic, the other below.

As an Eclipſe of the Sun can only take place at New Moon, if the Moon in the courſe of her revolution ſhould be at this period in the ſuperior part of her Orbit, her ſhadow when projected will paſs above the Earth, and hence no Eclipſe: if at this period ſhe ſhould be at or near the Node, ſhe will then be nearly in a right line, and her ſhadow will fall on the Earth.

There are more Eclipſes of the Sun than of the Moon, but more Eclipſes of the Moon viſible than of the Sun.

If the Moon's Nodes had no retrograde motion, there would be juſt half a year between the time of the Sun's conjuctions with the Nodes; the Eclipſes fall ſooner every ſucceeding year, as to prove that the Nodes move backwards 19 ½ degrees every year, hence go backward through all the ſigns in 18 years and 11 days. This was firſt aſcertained by Pliny, hence called

Plinian Period.

If to the mean time of any Eclipſe, either of the Sun or Moon, there are added 18 years, 11 days, 7 hours, 43 minutes and a half, will aſcertain the mean time of the return of that Eclipſe. As the Nodes go backwards 19 degrees, nearly equal to 19 days of the Sun's motion; hence taking half of this from 182 days and a half, or half a year, will remain 173 days for the time of the Sun's being in conjunction with the other Node.

Tranſits.

Mercury and Venus occaſionally paſs over the Sun's Diſk.

Mercury's Orbit is inclined 7 degrees to the Ecliptic, and his Nodes is in the 14th degree of Taurus, and 14th degree of Scorpion. The Earth is on theſe points on the 5th of November and the 4th of May, if Mercury is then near the Nodes, at theſe times there will be a Tranſit, appearing like a dark round ſpot upon the Diſk of the Sun. This takes place about once in three years, not always viſible to us.

Venus' Orbit is inclined 3 degrees and a half croſſing the Ecliptic in the 14th degree of Gemini and Sagittarius; as this Orbit is ſo large, it rarely happens that the Earth is in a right line with Venus and the Sun, when Venus is in her Nodes.

Dr. Halley having propoſed a method of determining the diſtance of the Sun from the Earth, by the paſſage of Venus over the Sun, to one-fortieth part of a ſecond. With this view ſome aſtronomers were ſent with Captain Cook in 1761 to St. Helena. There will not be another viſible one till 1996.

Tides.

The ancients had very imperfect ideas of Tides. Homer ſpeaking of Charybdis, ſays,

"*Thrice* each day it riſes."

There is little or no Tide in the Mediterranean, Charybdis is only a whirlpool in the Streights of Sicily. Herodotus, ſpeaking of the Red Sea, ſays there is a flux and reflux of water in it every day.

Horace ſpeaks of Tides as a phænomenon he had either ſeen or heard of,

"Quæ Mare compeſcant cauſæ."

There are a few places in the Mediterranean in which Tides have been obſerved, viz. the Syrtic, the Adriatic, the Faro of Meſſino, and the Euripus: the Faro and Euripus being narrow channels, are more currents; in the other two places Dr. Shaw particularizes Tides.*

Pytheas, of Marſeilles, who lived about the time of Alexander the Great, firſt ſuggeſted that Tides were governed by the Moon; Kepler was the firſt who attributed them to a principle of Gravitation.

Galilæo imagined Tides to be produced by the different velocities of the annual and diurnal motion of the Earth; which explanation would anſwer well, if the Tides occurred at noon and at midnight, and no variation in their riſe; but they are found to move through the 24 hours, and vary daily in their riſe.

Dr. Wallis, in 1666, ſurmiſed that the Earth and Moon having a motion round their centre of Gravity, according as the acceleration and retardation were coincident.

Sir Iſaac Newton, more partial to his ſyſtem of Gravitation, by a very laboured hypotheſis of the attractive powers of the Sun and Moon, endeavours to explain the phænomena of the Tides.

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* Varennius tells us of one philoſopher who imagined the Earth and Sea to be a living creature, and the Tides cauſed by its reſpiration; ſome imagined they proceeded from a great whirlpool in Norway, which for ſix hours abſorbs the water, and afterwards diſgorges it, &c.

Suppoſing a power of attraction to exiſt in all the ſpace between our Earth and the Sun and Moon, is attended with many difficulties: the following theory is offered.

The mean velocity of the Moon round the Sun is the ſame as the Earth; ſuppoſing the Moon of the ſame denſity as the Earth, its proportionate quantity of matter to the Earth will be as 1 to 49.22*. As the mean diſtance of the Moon from the Earth is 240,000 miles, the common centre of Gravity of theſe two Bodies will be inverſely as their weights from their reſpective centres, viz. 4896 miles from the centre of the Earth, 936 miles above the ſurface.

When on Gravitation it was obſerved, that this principle appeared probable to be that general impulſe which this Earth and all matter appertaining to it; has in conſequence of its orbitary revolution, that the diminution of Gravitation towards the equatorial parts correſponded to the counteractive, the annual motion of the Earth by the diurnal one.

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[*] As ſpheres being to each other as the cubes of their diameters; the Moon being 2161 miles in diameter, and whoſe cube is 10091699281; the Earth being 7920 miles in diameter, whoſe cube is 496792188000; theſe are to each other as 1 : 49.22. The greateſt diſtance of the Moon from the Earth is 256,785 miles, and its leaſt diſtance 223,211; therefore its mean diſtance is 240,000 miles.

A third motion of the Earth, round the common centre of Gravity of the Moon and Earth, will act with a power proportionate to the difference of this motion with the annual one.

When the Moon is in her quadratures, the centre of Gravity will lie very near the Line of the Earth's Orbit; the deviation from its annual motion is conſiderably leſs, the centrifugal power is proportionably ſo, and the Tides at this period are the leaſt. When the Moon approaches the right Line between the Sun and Earth, which Line being perpendicular to the Earth's Orbit, the common centre of Gravity of the Moon and Earth will alſo be perpendicular to the Earth's Orbit; the centrifugal power will be the greateſt, and the Tides will be Spring Tides or the greateſt.

The Tides are obſerved to be the greateſt at the time of the vernal and autumnal equinoxes, at a time when the revolution of the Earth round its Axis adds its greateſt centrifugal power to the motion round the centre of the Gravity.

When the Moon is in the Northern Signs at the Equinoxes, then the Tides in our Latitudes are the greateſt; ſo with the other ſide of the Line, when the Moon is in the Southern Signs.

Thus it is obſerved that the Tides in the Torrid Zone are the moſt violent, they diminiſh in their force as they approach the Pole. In ſeveral parts of the Northern Ocean are very ſmall; in the Baltic Sea, in Hudſon's Bay, little or none; while the Tides are very high in the Bay of Sunda, Malacca, Coaſt of China, Japan, Panama, Bay of Bengal, &c.

When the Earth is at the Solſtices, viz. about the 21ſt of June and the 24th of December, the Tides are the leaſt, inſtead of the motions of the Earth coinciding with the motion round the centre of Gravity, here are the moſt oblique, therefore the centrifugal power is the leaſt.

As the motion of the Moon is from Eaſt to Weſt, Waters which flow in this direction will have the greateſt Tides; if they flow from Weſt to Eaſt, the oppoſite motion is proportionably counteracted, as in the Mediterranean the Sea flows from Weſt to Eaſt, hence little or no Tide.

The Moon in her Apogæum is near 24000 miles more remote from the Earth than at another, hence the common centre of Gravity becomes two or three hundred miles more removed from the Earth, and when this coincides with the New and Full Moon, will make a variation in the Tides.

So alſo the Earth in different parts of her Orbit has different degrees of velocity, which alſo require to be taken into conſideration.*

Fixed

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* When the Moon is in the Syzygia, i. e. the Line which joins the centres of the Earth and Sun, ſhe has a ſwifter motion

Fixed Stars.

THE fixed Stars are diſtinguiſhed from the Planets by their never changing their relative ſituation, and *their ſcintillation**. To diſtinguiſh the Stars with regard to their ſituation, the ancients divided them into Conſtellations, digeſting them into the forms of ſuch animals, &c. which are delineated upon the Celeſtial Globe.

As the ancients had obſerved that the Planets moved in Orbits which formed ſmall angles with

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motion round the Earth; but in the Quadratures ſhe goes ſlower. The Moon, like all the other Planets, moves in Ellipſe, one of whoſe centres is the Earth, as ſhe deſcribes Areas proportional to the times, the motion of the Moon muſt be quickeſt in Perigeon, and ſloweſt in Apogeon.

The limits of an Analyſis will not allow to explain all theſe circumſtances, ſo far as they influence the Tides, which ſoon will be more largely treated of in a Work nearly arranged for the Preſs.

* Scintillation of the Stars is moſt in thoſe Stars which are neareſt the Horizon, ſeems to be produced by the intercepting particles of duſt floating in the Air. If a ſmall flat piece of glaſs, about the ſize of a ſilver penny, be laid upon the ground, between the obſerver and the Sun, with the plane of it a little declining from the Sun; when about 30 or 40 yards from it, the image of the Sun reflected from it appears bright and ſteady; when 3 or 400 yards, will twinkle in the ſame manner as the Stars do.

the Ecliptic, one half of their courſe on the North ſide, the other half on the South ſide, never exceeding 8 degrees from it; theſe were diſtinguiſhed by two leſſer circles parallel to the Ecliptic, one on each ſide; dividing this ſpace into Conſtellations, repreſented by animals, was called Zodiac, or Circle of Animals.*

Number

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* Zodiac. Macrobius firſt explained the reaſon of the Conſtellations; Cancer and Capricorn, thus being called, the one emblematical of the retrograde motion of the Crab, the other ſimilar to the aſcending of Goats in their feeding; Aries, Taurus, and Gemini, the chief attention of the Eaſtern nations were to their Flocks. Gemini, which now is repreſented as Caſtor and Pollux, in the Zodiac of the primitive times was repreſented by two Kids.

Leo repreſents the ſcorching heat of the Sun in July; Virgo ſignifies the gleaning Virgin; Libra the Equinox; Scorpio characteriſtic of autumnal Diſeaſes; Aquarius the rainy Seaſons; Piſces, when Fiſh moſt in ſeaſon.

It has been ſaid the ancients had only eleven ſigns, that Libra has ſince been added. Virgil, in compliment to Julius Cæſar, aſks him where he would chuſe to fix himſelf in his heavenly condition, mentions the Scorpion occupying two places, &c. So Ovid, when deſcribing the terrified ſituation of Phaëton, when he arrives at this part,

"Eſt Locus, in geminos ubi brachia concavat arcus,
"Scorpioſi & Cauda, flexiſque utrinque lacertis,
"Porrigit in ſpatium ſignorum membra duorum."

Virgil

Number of Stars.

PTOLEMY tells us that Hipparchus, the Rhodian, enumerated 1026; Bayer gave a liſt of 1160; Hevelius 1888; Flamſtead 3000 Stars; Antonia de Rheita counted in the Conſtellation of Orion above 2000 Stars. Dr. Herſchel's powerful teleſcope diſcovered 44,000 in the ſpace of a few degrees, which from proportion ſeem to indicate 75 millions in the Heavens.

According to the account of Hevelius, Caſſini, and others, the Stars are not immutable, ſome new ones appear and others vaniſh.

The fixed Stars are each Suns, probably illuminating their reſpective Planets as our Sun: it is ſuppoſed that theſe Suns, attended by all their Planets, have a general motion.

The Diſtance of the Fixed Stars.

THE moſt conſpicuous is Sirius: yet the Earth in moving round the Sun is at one time 198 millions

Virgil in another part mentions Libra,

> "Libra Diê ſomnique pares ubi fecent horas,
> "Et medium luci atque umbris jam dividet Orbem."

And Horace mentions them both,

> "Seu Libra, ſeu me Scorpius aſpicit."

lions of miles nearer than at another, yet the magnitude of the Star does not appear the leaſt altered.

To aſcertain the diſtance, Gregory ſuppoſed Sirius to be of the ſame bigneſs with the Sun, and to have the ſame apparent diameter as Jupiter in Oppoſition. Huygens ſays their diameters cannot be meaſured, as being only lucid points; he adopted another mode, by which he aſcertained it to be 27,664* times farther than the Sun. Caſſini's method was equally hypothetical, who only made it 384 times as far as the Sun.

This has been more accurately determined by the great diſcovery of Dr. Bradley, on the Theory of the Light's Motion; his obſervations were made on a Star in the Head of Draco to be 10,210 times greater than the diameter of the Earth's Orbit, by a theory now called by aſtronomers

The Aberration of Light.†

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[*] Huygens covered one end of a twelve foot empty tube with a very thin plate of braſs, wherein he had pierced a very ſmall hole, not exceeding the 140th part of an inch, which reduced the Sun to 182d part of his whole diameter; he appeared much brighter than Sirius: a ſmall globule of glaſs of the ſame ſize of the hole was put in, and which reduced it to the 152d part of 182, equal to 27,664.

[†] ABERRATION OF LIGHT. Ricciolus and others objecting to the Copernican ſyſtem, that if the Earth moved in an an-

nual Orbit round the Sun, there would be a difference obſerved in the meridian altitude of a fixed Star, in the ſame place of obſervation at different ſeaſons, called the Earth's Annual Parallax, being that angle under which the diameter of the Earth's Orbit would be ſeen from that Star, if this bore any proportion.

Dr. Hooke, to determine this, directed his teleſcope, fixed in the roof of his houſe, of 36 feet, to the bright Star in the Head of Draco, which paſſeth nearly over the vertex of London: the angle he determined to be 27 or 30 ſeconds, about 17,000 times as far off as the Sun. Flamſtead found this incorrect: in order to have a ſecure building, he fixed the arch of a circle to a ſtrong wall at Greenwich, now called the Mural Arch, and found it after 7 years, 40 or 45 ſeconds.

The inſtrument was no ways accurate. In 1725 Dr. Bradley made uſe of one made by Graham; the reſult of many obſervations were, that the Star appeared more northerly in December than in June, contrary way to what it ought to be from the annual parallax. Dr. Bradley concluded this to ariſe from the progreſſive motion of Light. This angle he found to be about 30 ſeconds, and which is in proportion to the angle at the Baſe as 1 to 10,799; ſo that the motion of Light is ſo many times greater than that of our Earth, and the diſtance of the Star 10,799 times the diameter of the Earth's Orbit, viz. 2033408000000 miles.

ADDENDA.

ADDENDA.

AS the explanation on mechanical principles of thoſe experiments which are generally adduced to demonſtrate the exiſtence of certain active powers, as *Attraction* and *Repulſion*, had been fully given in a volume of Philoſophical Eſſays lately publiſhed; in the Analyſis reference has been given to this work: the Author underſtands from the Printer that there are not many Copies left, on which account he has thought proper to tranſcribe from the aforementioned work, what peculiarly relates to theſe experiments.

EXPERIMENT I. *The tendency of light Bodies floating on the ſurface of Water contained in a veſſel, towards the ſides of that veſſel.*

When a glaſs veſſel is nearly filled with water, a thin glaſs bubble, or a piece of cork, placed on the ſurface, moves with an accelerated force towards the ſide of the veſſel.

In floating a body which is ſpecifically heavier than water, but whoſe gravity is not ſufficient to overcome the combinatory union of the particles of water, as a needle ſwimming on water, a contrary effect is obſerved; the needle avoids the ſides of the glaſs, and tends towards the centre.

If the glaſs veſſel be filled to the utmoſt with water, theſe effects are reverſed; the glaſs bubble flies from the edges, and moves with rapidity towards the middle; the floating needle in this caſe does not retain its central ſituation, but moves with an increaſing velocity towards the ſides.

In either caſe, a large ſolid ſtick of glaſs no ways influences the bubble or needle, however near applied, unleſs the ſtick touches the water.

Theſe effects are the neceſſary reſults of the fluid varying in its height.

In a half filled glaſs, the fluid is higheſt in that part where it is in contact with the glaſs, and loweſt in the centre; as bodies ſpecifically lighter than the fluid on which they float, muſt riſe to the ſuperior part, the cork or glaſs bubble will from hence approach the ſides of the veſſel, while a needle being ſpecifically heavier, will deſcend to the loweſt part.

Thus melted lead, when left to cool in a veſſel, has always a depreſſion towards the centre.

When a glaſs is more than filled, the water is higheſt in the centre, and loweſt towards the edge; in this caſe the ſpecifically lighter body will move towards the centre, and the heavier one towards the circumference.

Fluids move in that direction where they meet with the leaſt reſiſtance; a fluid confined in a veſſel tending towards the centre of the Earth, meets with leſs reſiſtance in its central portion, than in that part where in contact with the ſolid body, which limiting the preſſing action of the whole fluid, renders it the higheſt in the circumference.

When a veſſel is more than filled, the edge of the fluid is in contact with Air, where it meets with leſs reſiſtance than in its central portion, in this caſe the fluid hangs over the edge of the veſſel, the gravity of the fluid not overcoming the combinatory union of the particles of water; hence the circumference will be the loweſt.

The Riſe of Fluids in Capillary Tubes.

WHEN a tube of a ſmall bore is immerſed in water, the fluid riſes to a certain height above the level. If a tube twelve inches long, and whoſe bore does not exceed the twentieth part of an inch, be divided into twelve parts, when one part is immerſed in the fluid, the water riſes near one inch and a half in the tube above the level; when two parts of the tube are immerſed, the aſcent is about one inch and a quarter; when three parts are immerſed, the difference is ſtill leſs; when ten parts are immerſed, the riſe is not more than a quarter of an inch; when the whole tube is immerſed, the aſcent is nothing.

If the ſides of the tube cauſed the fluid to riſe by virtue of any attractive power, why ſhould there be this gradation in the aſcent of the fluid?

Theſe effects ariſe from the different elaſticity of the Air; the elaſticity of the Air is always a counteracting balance to the general preſſure of the Atmoſphere: as a diſtended bladder preſerves its diſtenſion, becauſe the elaſticity of the included Air is equal to the preſſure externally. As the elaſticity of the Air is the action and reaction of its conſtituent particles in a minute column, there cannot be the ſame elaſticity as in the ſurrounding unconfined Air. When the tube is immerſed in the water, the preſſure of the outer Air will cauſe the water to riſe; when the tube has more of its parts immerſed, then the aſcent is not ſo great, becauſe the Air in the tube out of the water being nearer the Atmoſpheric maſs, neceſſarily increaſes in its elaſticity, and proportionably reſiſts the riſe of the water; this reſiſtance increaſes the leſs portion of the tube there is out of the water, till ultimately the reſiſtance is equal to the atmoſpheric preſſure.

A fluid will riſe to a certain degree, when the upper end of the tube is not open; alſo an electrical ſpark will ſtrike a conducting body at a greater diſtance thro' a ſmall tube, than thro' the open Air.

It may be objected to this, that the fluid will riſe in tubes placed within an exhauſted receiver; in the imperfect manner a receiver is exhauſted, the ratio of the elaſticity of the Air in the tube to that of the receiver will be the ſame as above.

The Force with which two poliſhed leaden Hemiſpheres cohere.

WHEN two poliſhed leaden, or other ſoft metallic Hemiſpheres are rubbed together with a rotary motion, they cohere with ſuch power as to require a weight for their ſeparation conſiderably more than what would be requiſite for the ſeparation of exhauſted Magdebourg Hemiſpheres of the ſame ſize, Two leaden Hemiſpheres, of about an inch and a quarter in diameter, will require 150lb. to ſeparate them.

When the planes are placed upon each other, and preſſed with ever ſo great a weight, there is no coheſion produced. No ſuch effect is induced by the application in any mode of braſs or iron Hemiſpheres. When a leaden Hemiſphere is examined after the coheſion has been produced, the ſurface appears covered with ſpiral lines and ridges, where particles of the lead are raiſed up.

From this circumſtance the power with which they unite is eaſily explained.

The reverſe rotary motion round the axis of each Hemiſphere raiſes up on each plane particles of the lead in contrary directions, ſo that all the particles of the one being locked with thoſe of the other, will reſiſt ſeparation in proportion to the number of particles thus entangled. However ſtrong the

Hemiſpheres are united, they do not in the leaſt reſiſt the ſame rotary motion which induced the union. When the Hemiſpheres have thus been uſed two or three times, the ſurfaces become ſo irregular, that no union can be induced till the ſurfaces are ſcraped.

Theſe circumſtances, which have been adduced as proofs of the exiſtence of certain powers, are reducible to pure mechanical principles; ſo alſo Gravitation, Optics, Electricity, and the Doctrine of the Tides, have been ſimilarly explained in the foregoing Analyſis, as copiouſly as the limits of ſuch outlines will admit. Theſe *Powers*, as well as the nature of a *Vacuum*, the Author has preſumed to reject in this Syſtem of Philoſophy; he is in hopes that the ground-work will be clear and evident, when the fundamental principles are cognizable to every mind. When he firſt commenced the ſtudy of philoſophy, he found himſelf embarraſſed by crouds of *Powers*, *ætherial Atmoſpheres*, *attractive and repulſive Influences*, &c. not being enabled to conceive their exiſtence, he felt himſelf diſcouraged in his purſuits, and attributed to his own inability, what he now finds incomprehenſible to all.

If by any exertions of his the ſtudy of Philoſophy ſhould any ways be facilitated, if by any explanation he has attempted, the fundamental principles ſhould be eaſier comprehended, his purpoſe will be fully anſwered.

ELEC-

ELECTRICITY.

The Eſſay on Electricity has been publiſhed ſome time; as it contains the outlines of the Lectures on this Branch of Natural Philoſophy, it has been thought adviſeable to annex it to the Analyſis inſtead of reprinting it. In additional confirmation of the Theory there advanced, the Author begs leave to add the following remarks.

Pith balls placed under a receiver exhauſted of Air to its greateſt degree, do not diverge on the application of Electricity.

In condenſing Air, in an inſulated braſs ball on which are ſuſpended two pith balls, on the firſt condenſation the balls diverge with poſitive Electricity; on continuing the condenſation, caloric is then given out: when the Air is diſengaged, the balls diverge with negative Electricity. Caloric is abſtracted from ſurrounding bodies, a conſiderable degree of cold is induced.

A lighted taper placed between two balls of an univerſal diſcharger, the flame will be in an oppoſite direction to that ball which communicates with the poſitive ſide of the Leyden Jar.

A Leyden Phial placed under an exhauſted receiver cannot be charged; even when charged, as the exhauſtion goes on, the Electricity equalizes itſelf. When two Atmoſpheres are condenſed into the ſpace of one Atmoſphere, the charge of the Leyden Phial is proportionally increaſed.

Cuthbertſon's Electrometer, in its action ſimilar to Brooks, in the form of a balance, the end communicating with the poſitive ſide of the Jar a few grains heavier than the other arm, underneath which is placed a ſliding rod with a ball, communicating to the negative ſide. The intenſity of the charge will be meaſured by the diſtance between the ball of the ſliding rod and the ball of that arm of the balance which is not connected with the poſitive ſide of the Jar.

As the Jar is charging, the balance participates of the intenſity; in this ſtate poſſeſſes more than the ſurrounding Air, the Air acted upon by this ſurcharge, reacts on the ball; that portion of Air between the two balls reacts leſs than the Air above the ball, owing to the action of the Electricity in the balance, cauſing the Air placed between it and the ball of the ſliding rod to unload itſelf of an adequate quantity of Electricity; ſo that the reaction of the Air above the ball being greater than from that below, the ball is preſſed downwards, and the diſcharge takes place. As the reſiſtance to overcome is in proportion to the diſtance, this becomes a meaſure of the intenſity.

FINIS.

AN

ESSAY

ON THE

NATURE AND CONNECTION

OF

HEAT,

ELECTRICITY,

AND

LIGHT.

Sir

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1800.

PREFACE.

6-22-34

The preſent age is peculiarly diſtinguiſhed for aſſiduity and accuracy of reſearch into the laws of nature, and by the general attention which the ſubject has excited.

Carried along by the ſtream, I have been ſometimes drawn into theſe inquiries, and without aiming at a compleat acquaintance with every branch of the ſcience, have yet endeavoured to acquire a competent knowledge of the leading facts proved, and the inferences drawn from them, in hopes to convey to my own mind a general view of the ſyſtem of nature.

With this purpoſe I began to conſider the nature and action of Heat, which ſeems to be at preſent the leaſt underſtood of any equally important branch of natural knowledge; but with all the aſſiſtance of the very able diſquiſitions upon the ſubject, I could ſcarcely perceive any thing like a general plan in its operations. Knowing that few men can think with accuracy, until by committing their ideas to paper, they analyze and concentrate them, I ſat down to examine by that teſt the opinions which I had formed. I found the effects diſproportioned to the apparent cauſe; and accordingly looked around for ſome other agent to whoſe miniſtry I might aſcribe her works; for the powers of nature, like her productions, never appear ſolitary. All her ſprings are combined in action, to produce that harmony which blends into uniſon her varied works.

LITTLE difficulty occurred in the ſearch. Every thing pointed out electricity as the active power to whoſe exertions, in combination with thoſe of heat, all theſe effects are aſcribable. The ſame chain of inquiry led me to examine the connexion between theſe two forces, and between them and their common relation, light. I have given the reaſons which induce me to believe, that they are three appearances of the ſame ſubſtance.

DISCUSSION is always beneficial to ſcience, and the ſubject of this Eſſay is ſo intimately connected with the firſt principles of natural knowledge, that any new ſuggeſtion upon it, if ſupported by an appearance of reaſon, cannot be wholly unworthy of notice. I am therefore induced to ſubmit my ſpeculations to the public eye, that they may undergo the examination of others more able than myſelf to judge of their value, to approve or to condemn them.

THE order and arrangement of the different matters diſcuſſed, might, perhaps, have been more methodical: but I am not anxious to have it believed, that at the firſt view I perceived all the concluſions into which I was afterwards drawn; and I thought it would be more clear and ſatisfactory, to exhibit the chain of my inquiries in the order in which they occurred to me, that the ſame doubts may ſuggeſt to others the ſame explanation. This is not a treatiſe to arrange and elucidate known doctrines; it is a ſpeculative eſſay.

Perhaps the circumſtances under which theſe ſheets were compoſed, may afford ſome claim to indulgence for any errors they may be found to contain. They are the produce of the few leiſure months which were given me after abandoning the active exerciſe of my profeſſion at home, until I was able to reſume it here; they were compoſed principally at ſea, where I had neither ſufficient books to reſort to, nor the converſation of philoſophical friends to correct my miſtakes.

If the phænomena which have given riſe to the reflexions contained in this eſſay, can be better explained by any other chain of reaſoning; or if, when canvaſſed by ſuperior talents and learning, objections, hid from my eyes, ſhall be diſcovered, I ſhall ſtill recollect, with ſatisfaction, that I have exerted my abilities, ſuch as they are, towards advancing our knowledge of nature. In a purſuit ſo alluring, and ſo intereſting, our labour is its own reward.

Madras, 30th October, 1798.

AN ESSAY ON THE NATURE AND CONNECTION OF HEAT, ELECTRICITY, AND LIGHT.

UPON obſerving the texture of any ſolid body, it appears to us ſcarcely to be accounted for, that by any change within itſelf, its particles ſhould aſſume the liquid form, or afterwards the gazeous or vaporous. Theſe changes are produced by increaſe of heat; by what proceſs are they effected?

SOLID bodies ſeem to be held together in that ſtate by different cauſes. Of theſe, the principal are the mutual attraction and adaptation of the particles, which prevent any one from being moved without violent

B friction

friction againſt thoſe adjoining. Secondary cauſes of the compact form of the body are, the attraction of coheſion, the preſſure of the atmoſphere or ſurrounding objects, and its own gravitation. Upon its aſſuming the liquid ſtate, the two former cauſes are evidently overcome by ſome ſuperior force. The particles are no longer held in cloſe and firm contact; but the latter cauſes ſtill retain them in one body, and prevent them from riſing into vapor. After this change they no longer preſent any mutual obſtruction, but glide eaſily paſt each other, without friction or colliſion; at the ſame time the temperature is diminiſhed, or heat appears to be abſorbed, and the capacity of the body for heat is proportionally increaſed. Theſe effects being produced by the mere addition of heat, the explanation of the proceſs and means employed muſt be ſought in the nature of that ſubſtance.

The prevalent theory upon the ſubject is this, that heat, or caloric, is a fluid, highly elaſtic, known only in combination. The proportions in which it enters into the compoſition of bodies at the ſame temperature are infinitely various, according to the different admiſſion which each body preſents to it from the conformation or poſition of its particles. As light eaſily penetrates through, and finds pores in the hardeſt ſubſtances, while many of the moſt looſe in texture repel its entrance, ſo heat, intimately connected with light, finds for itſelf pores or entrances, the ſize and number of which can only be gueſſed at from the effect. The temperature marks the denſity or compreſſion of the heat in thoſe pores which are preſented for its admiſſion. If by a change in the form or poſition of the particles, thoſe pores are enlarged or multiplied, the temperature or compreſſion of the heat muſt be diminiſhed; and as there is more ſpace for the whole heat, it will require a greater addition to raiſe it to any given increaſe of temperature or compreſſion; that is, the capacity for heat muſt be increaſed. Therefore, when a change of capacity and temperature takes place, the cauſe is looked for in ſomething which has altered the form or poſition of the particles, ſo as to open more ſpace for the heat.

The poſition or form of the particles of bodies while ſolid, is ſuppoſed to reſiſt the admiſſion of the heat into many of thoſe pores which it otherwiſe might fill. Heat, conſidered as an elaſtic ſubſtance, muſt acquire additional elaſtic force by an addition of quantity in the ſame ſpace. When accumulated to a certain degree, it is ſuppoſed to have overcome the coheſion of the particles of the body, and changed their poſition, ſo as to gain admiſſion into ſpace or pores before ſhut againſt it. Thus the temperature or compreſſion of the heat muſt be diminiſhed, and the capacity increaſed. The fluidity of the maſs is accounted for, by aſſuming that the pores newly opened, are thoſe which intervene between the particles of the body; ſo that each particle, minute beyond the perception of our ſenſes, enveloped in its coat of heat, glides through the others without a poſſibility of touching them, or meeting with any obſtruction in its paſſage.

We obſerve that all bodies, in aſſuming the ſolid ſtate, cryſtallize into regular figures. This can only be accounted for by ſuppoſing that the particles, from ſome ſort of polar attraction between their correſponding extremities, are led to aſſume thoſe forms. Heat, in producing fuſion, certainly affects the polarity of the particles; for we find their poſition for tranſmiſſion of light and of electricity materially changed by it. We may therefore reaſonably infer that the effect of fuſion is produced by deſtroying that polarity, or attraction of the correſponding extremities of the particles, which gives them the conſiſtent appearance of ſolidity.

The increaſe of ſize of bodies by heat, without change of form or of capacity, is not ſo eaſily explained. The heat ſtruggling to enlarge its ſpace, has in fact increaſed the bulk of the maſs; yet its compreſſion or temperature is not diminiſhed.

The increaſe of bulk of water by cold, at eight degrees above the freezing point, reverſes the phenomenon and increaſes the difficulty.

Any cauſe which diminiſhes the coheſion of the particles, will facilitate the operation of heat in producing fuſion. Thus if two bodies are mixed, having a ſtrong mutual attraction, this may counteract and diminiſh the coheſive force of the particles of each; accordingly the heat, meeting with leſs internal reſiſtance, produces fuſion at a temperature which might not have diſſolved either body ſeparately. Such is ſuppoſed to be the proceſs in the mixture of ice or water with ſalts; in ſolutions of metals in acids; of earths together, or with acids, or alcalis; and generally in ſolutions in menſtrua.

But ſome bodies in combination exhibit the oppoſite effect. Metals in fuſion combining with gas oxygen, the fluidity of both is deſtroyed. Many aſſiſt each other in fuſion, which ſeem to have no tendency to unite in any ſtate; as metallic ores, and their fluxes. Theſe contradictory appearances ſeem ſcarcely capable of a common explanation from any known qualities of heat alone.

The next great change produced in bodies by increaſe of temperature, is evaporation, or volatilization. When the heat interpoſed between the particles is further increaſed and condenſed, it is conſidered as making new efforts to enlarge its bounds. The body is ſtill held together by the attraction of coheſion, the preſſure of ſurrounding bodies, and its own gravitation. The particles below the ſurface are alſo preſſed by the weight of thoſe above them in the fluid maſs. When by increaſed condenſation, the heat has acquired ſufficient elaſtic force to overcome theſe obſtacles, it expands the body into vapor.

In this operation the heat muſt be conſidered as having either penetrated into new pores of the body, or diſtended thoſe it before filled. The former ſuppoſition accords beſt with the explanation given of the change from the ſolid to the fluid ſtate. It may thence be inferred, that this ſecond tranſition is effected by another change of poſition of the particles, or rather by a more minute diviſion of them, and a change of the relative poſition of the component parts of thoſe larger particles which were before the ſmalleſt diviſions of the body *.

As evaporation takes place when the elaſticity of the condenſed heat is ſufficient

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* The application of electricity to fluids has the effect of perceptibly ſubdividing the particles; a further charge volatilizes the body. I ſhall have occaſion afterwards to ſhew how nearly theſe effects of electricity are connected with thoſe apparently produced by heat alone.

to overcome the oppoſition it meets with, the leſs that oppoſition is, the ſooner will the effect be produced. One obſtacle is the weight of the incumbent atmoſphere; the period of evaporation is accordingly proportioned to it. So the attraction of other ſubſtances, by diminiſhing the internal coheſion of the body, may facilitate the operations of the heat. Thus water is taken up in great quantities by atmoſpheric air at any temperature. This appearance exactly correſponds with the ſolution of ſolids in fluid menſtrua. In both caſes the ſame changes of capacity and of temperature are perceived, as when the effects ariſe from heat alone. We are therefore to conclude, that the ſame cauſe, heat, produces the change in all the caſes; and that the attraction of the menſtruum has no other effect than to counteract the internal coheſion of the particles, which reſiſted the operation of the heat.

Such I believe to be nearly the outline of the preſent received theory of the nature and action of heat, and ſeems to be the neceſſary reſult of the opinion, founded upon the apparent fact, that theſe changes in bodies are the effects of this power alone. I proceed to inveſtigate the detail and conſequences of this ſyſtem.

SECTION II.

It ſeems to be eſtabliſhed, that every body, while it retains the ſame form, whether ſolid or fluid, has its capacity uniform; and the theory of heat ſuppoſes that increaſe of capacity upon a change of form, ariſes from the increaſed ſpace opened for the admiſſion of the heat. From this I was at firſt led to expect that the ſpace requiſite for the body, upon the change to the gazeous form, muſt bear a very near proportion to the new ſpace opened for the heat, or in other words, to the increaſe of capacity. For as the particles of matter are incapable of filling more or leſs than a certain ſpace, and as the only body apparently interpoſed is the heat, it would ſeem to follow, that the whole of the increaſed ſpace muſt be filled with that fluid. So it might be ſuppoſed that in two gazeous bodies at the ſame temperature, and of the ſame bulk, the abſolute heat muſt be reciprocally as their weight; for the denſity of the heat and the whole ſpace being equal, the leſs of that ſpace is filled with the body, the more muſt be occupied by the heat. Upon conſidering the fact, I was aſtoniſhed to find how far theſe concluſions are wide of the truth.

In the boiling of water, the ſteam is found to occupy, at that temperature, about 1800 times more ſpace than the water: but the whole increaſe of abſolute heat is about one-third; which being of the ſame denſity, cannot occupy that proportion of additional ſpace. When a cubic inch of water is evaporated ſo as to occupy 1800 cubic inches of ſpace, leſs than 1⅓ inches are alone filled with the body and heat; there remain 1798⅔ cubic inches to be accounted for.

By what is this enormous ſpace occupied? Not by the expanſion of either of the ſubſtances, the gazeous body or the heat; ſuch enlargement would be contrary to all our ideas of the principles of matter. The heat in particular being of the ſame temperature or denſity, has not been expanded; the diſtention of the maſs muſt therefore ariſe from ſome repulſive power exiſting in the compound.

THAT repulſion muſt either reſide in the body or in the heat; or it muſt ſpring from ſome other ſource. The laſt appears to me to be the moſt probable concluſion; I aſcribe the effect to electricity.

HEAT does not in any caſe ſhew a repulſive power, which cannot be clearly traced to its well known property of exciting electricity.

The gazeous body, ſeparated by the elaſtic force of the heat, may be ſuppoſed to exert a repulſive power from the ſuperficies of each particle; for it is clear, that no two particles in the cloſeſt body are ever in abſolute contact; but are only held together at a certain approximation, within which their mutual repulſion prevents them from encroaching. This repulſion, increaſed by the heat, may be ſuppoſed to produce the effect of evaporation. But what is this repulſion? It is clear that every body, and every particle of it, contains a portion of electricity; and as the powers of attraction and repulſion are found much more ſtrongly in this than in any other ſubſtance, it is more conſonant to the rules of philoſophy to aſcribe to it the whole of thoſe effects, if poſſible, than to give the denſer body a ſeparate attractive and repulſive power, beſides that which its electricity communicates. The leaſt change in the electricity of the body materially affects the attractive and repulſive tendencies of the maſs; they muſt therefore be conſidered as ariſing wholly from this cauſe.

To give this propoſition its proper ſtrength, and to diſcover its conſequences, it will be neceſſary here to mention ſo much of the known facts, or probable deductions, concerning the nature of electrical attractions, as applies to my preſent purpoſe.

Bodies filled with ſimilar electricity repel each other; oppoſitely electrified, they are mutually attractive *. Some bodies

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* It ſeems unneceſſary here to inquire at length into the cauſes of theſe ſeveral phænomena of electricity. Perhaps they are in truth only different directions of the ſame force. Thus we may conſider the creation as being filled with two electrical fluids attractive to each other, and therefore producing attraction in the bodies which they occupy; or, according to the Franklinian theory, with one fluid, whoſe tendency to equal diſperſion produces the ſame attraction in bodies unequally filled with it. When a body is equally attracted on all ſides, it will appear to lie at reſt, or in the equilibrium of electricity. When two bodies, by being differently ſupplied with electricity, have a ſtronger mutual attraction than either has for the ſurrounding objects, they will ſhew this power in motion or active exertion. Where two bodies are in an electrical ſtate more nearly

ſimilar,

are found to have in a very great degree, probably all poſſeſs more or leſs, the power of ſeparating the electricities into vitreous and reſinous, or poſitive and negative diviſions. Thus a white and a black ſilk ſtocking or ribbon, cloſely preſſed together, become oppoſitely electrical, and of courſe mutually attractive. The tourmalin, and many other bodies, when heated, analize the electricities in the ſame manner. If the minuteſt fragment of a tourmalin be taken, it has its poſitive and negative ſide; ſo if two or ten thouſand particles of ſilk, white and black, of ſimilar texture with the ſtockings, were mixed and laid alternately in the ſame cloſeneſs, every contiguous black and white particle would analize the electricity, and become mutually attractive; of courſe the maſs muſt cohere. In ſuch a maſs however, as the different particles

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ſimilar, and become therefore leſs attractive mutually, than either is to the objects around, the attraction of theſe objects being no longer counteracted by an equal force, becomes active in the direction oppoſite to the body which has ceaſed to attract; and which will therefore ſeem to exert an active repulſive force.

particles are equally diſperſed, and preſented in equal numbers to external objects, the whole muſt appear in the common equilibrium of electricity. This ſeems to me to be nearly the proceſs of attraction between the particles, or the correſponding extremities of the particles of bodies, which gives them the coheſion of ſolidity.

THE excitation of electrics by friction ſeems to ariſe from the ſame cauſe; the two bodies tend to divide the electricities between them, but this tendency is not ſufficiently ſtrong to produce any powerful effects, unleſs by friction a greater proportion of their ſuperficial particles are brought ſucceſſively into contact. The electricities thus ſeparated may be conveyed to other bodies, and charge them.

THERE is this difference, however, between the mutual attraction of bodies differently electrified by external cauſes, friction, or communicated electricity, and that of two particles or bodies, which tend to analize analyze that fluid. In the former the attraction ariſes from the tendency to communicate electricity, to reſtore the equilibrium: when that is effected the attraction ceaſes. But the two ſtockings are attractive by their tendency to deſtroy the equilibrium. It is evident that this attraction is not compleat; it is only a tendency to keep the bodies ſo near as to analyze and ſeparate the electricities. Compleat and perfect union is inconſiſtent with this tendency, and therefore attraction and repulſion are both neceſſary to it. This I take to be the cauſe of elaſticity in ſolid bodies, and the origin of that repulſion which prevents their particles from coming into contact. When, therefore, I perceive this repulſion increaſed, ſo as to diſtend the body into vapor, I conclude that it ariſes from electricity, the active cauſe of the repulſion, not from any affection of the paſſive and inert particles of the groſſer body.

We find that heat has the moſt powerful effects in altering the electrical ſtate of bodies. All are changed by it, but no fixed principle can yet be traced in its operations. The ſame temperature electrifies ſome bodies poſitively, ſome negatively, ſome it leaves in the equilibrium. Bodies which do not otherwiſe ſhow any ſtrong electrical habits, become powerful electrics by heat; others, which in a moderate temperature exhibit ſtrongly thoſe affections, are brought by great refrigeration, or exceſſive heat, to the common level. Theſe changes muſt be produced by an alteration in the diſtribution of the electricity in the particles of each body. But ſuch an alteration may alſo take place without any external electrical appearance, provided the whole quantity of electricity preſented to other objects continue the ſame.

It is ſome internal change in the diſtribution of electricity in bodies, which brings them to the gaſeous ſtate. In place of that electrical inequality of the particles by which they were retained in coheſive ſolidity, they became ſimilarly electrical, and therefore repulſive. Probably each particle, having before a poſitive, a negative electrical extremity, now arranges the two electricities differently, incloſing the one within it, and being incircled by the other. The ſurfaces of all the particles become thus ſimilarly electrical, and exhibit that repulſion which is found to exiſt between them in evaporation.

As heat produces evaporation through the medium and by the force of electricity, the latter power, when excited by any other cauſe, muſt have the ſame effect. Electricity evaporates fluids.

In retracing the effects upon the bodies apparently produced by heat alone, we may clearly diſtinguiſh this principle of electricity materially active in each. Fluidity requires ſufficient repulſion to prevent the particles from touching, or tending to coaleſce. Probably the ſame arrangement of electricity, which, when ſtronger, produces evaporation, takes place in non-elaſtic fluids, each particle ſeparating the electricities between its external and internal coats. The mutual repulſion ariſing from this tendency, preſents a more probable explanation of fluidity, or of the free paſſage of the particles without colliſion, than the interpoſition of caloric, which is not otherwiſe proved to have ſuch repulſive power.

The particles of fluid bodies have very feebly, if at all, the power of mutually communicating heat; if nothing but heat were interpoſed between them, why ſhould not its tranſmiſſion be free?

To the ſame principle we may trace the elective attractions of heterogeneous bodies. They are found to be much affected by temperature, and therefore ſeem to flow from the various effects of the heat on the ſeveral electrical habits. If the tourmalin is heated upon glaſs, the former becomes poſitively electrical, the latter negatively; of courſe they are mutually attractive. Solutions of bodies in menſtrua, and all chemical combinations, probably flow from the ſame ſource. So the aſſiſtance which different bodies give to each other in fluxion, ſeems to ariſe from their different electrical ſtates at the given temperature, producing mutual attractions, which ceaſes in ſome by the ſecond electrical change occaſioned by the fuſion. The oxydation of metals, and the formation of water, ſhew the different effects of the heat at the reſpective temperatures on the electrical habits of the oxygen, and of the metal or hydrogen, creating in each caſe that attraction which conſtitutes combuſtion.

In combination, it is not neceſſary that the whole of either body ſhould outwardly appear electrical, in order to produce the attraction; for if one body tend to analyze the electricity ſtrongly, or at large intervals between its particles, and the electrical diviſions of the other be leſs ſtrongly marked, this will be poſitively electrical to the negative particles of the former, and negatively to thoſe which are poſitive, and ſo attract both.

It generally happens in combination, that a certain temperature gives the attraction which produces the union, a greater or leſs deſtroys it; as in the ſolution of ſalts in water, the oxydation of metals, &c. This cannot, I think, be explained upon any known qualities of mere heat, otherwiſe than as it is found variouſly to excite the electricity of the bodies. The latter muſt, therefore, be conſidered as the immediate agent in theſe changes.

As heat produces or deſtroys combinations by the agency of electrical attractions, the ſame effects muſt follow from any other cauſe which produces the ſame changes in the electrical ſtate of the bodies, and therefore gives the ſame electrical attractions. It is not, however, in many of theſe her more delicate operations and intricate arrangements, that we can imitate nature. In ſome we can: thus the electrical diſcharge corrodes, and gives the ſame colored rings to metals as heat; theſe appear to be oxydations.

Upon the ſame principle I think it is, that we muſt account for another very conſpicuous effect of electricity. Paſſing through oxygen and hydrogen, it combines them into water. This has generally, but I think erroneouſly,+ been aſcribed to the heat of the electric ſpark. It takes place in the atmoſphere in every cloud of vapour or ſhower of rain; theſe appearances are always accompanied with ſtrong electricity, and being generally without luminous ignition, muſt be attributed to the common attraction of matter, for the purpoſe of reſtoring the electrical equilibrium when diſturbed. Electricity is here the ſole agent. Heat does not appear even as a ſtimulus to its exertions. We find alſo, that an exceſſive degree and repetition of the electric ſhock, can decompound water into its original gaſes, which heat cannot effect.

+ Why erroneously = It takes a very considerable number of Electric Sparks to reduce a very few cubic inches of these Gases into water LD

There is therefore every reaſon to believe, that in combination, or decompoſition, heat is only a mode, not always the moſt efficacious, of applying or exciting the electricity, which gives or deſtroys the requiſite attraction.

The formation of water is a ſubject which, both from the diſcuſſion it has occaſioned among philoſophers, and from its own importance, claims our utmoſt attention: and as the great changes diſplayed in the atmoſphere preſent the operation of every natural cauſe upon a ſcale infinitely larger, and therefore leſs equivocal, than any experiments of our own, and perhaps contain powers which we are unable to imitate, and have therefore not ſufficiently attended to, I was anxious to examine, whether the opinion which I had formed correſponded with thoſe great appearances of nature. The production of vapor, rain, and thunder-ſtorms, is ſo clearly reconcileable to the ideas here ſuggeſted, that it would be ſuperfluous to trace the proceſs of their formation. I was ſurpriſed, however, to find one appearance, the production of hail, incapable of explanation upon any principle which I had before perceived. The inveſtigation of its nature, led me to obſerve more accurately the operation of the two great powers, heat and electricity, and to form important concluſions concerning the connexions between them.

SECTION III.

THE common theory of the origin of hail, ſuppoſes it to be merely rain collected in ſo high and cold a region of the air, as to aſſume the ſolid form. But I know no reaſon to believe, that hail-ſtorms proceed from clouds more elevated than others which give rain. The hail which falls on high mountains is extremely ſmall, from the thinneſs of the atmoſphere which ſupplies it; but in lower grounds, hail generally contains as much water in each hail-ſtone as the largeſt rain. It is frequent in hot weather, when the air is heated, and its electrical inequalities ſtrong and frequent; but it is ſeldom found to fall in winter in cold climates, when the air is cold, and electrical effects weaker. This ſeems to connect its origin with electrical cauſes, not with the permanent temperature of the air.

THE aqueous vapor, in being condenſed into rain, diminiſhes in capacity about one-third, and in being frozen one-tenth more *. If, therefore, the whole be one inſtantaneous operation †, the vapor muſt have been about 584 degrees below the freezing point!

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* This eſſay having been written on ſhipboard, where the author had not acceſs to any books containing the accurate proportions of heat abſorbed, they are here ſet down in round numbers; but, it is hoped, with ſufficient correctneſs for the purpoſe to be anſwered.

† It is plain that if the vapor were not collected into a hail-ſtone, by the ſame inſtantaneous operation which firſt gives it the non-elaſtic form, it muſt, at the ſame temperature, be frozen in any previous appearance in the non-elaſtic ſtate, in the looſe ſhape of ſnow, and never could afterwards be collected into hail.

If from the ſize of the hail-ſtones we conclude, that the firſt internal globule only is formed in the upper air, and that in its deſcent it meets with aqueous vapor, which it freezes around it, the calculation will be ſtill more enormous. Let us ſuppoſe the original hail-ſtone to have been only one-fifth of the whole, and to have collected around it and frozen, four times its own portion of vapor; each of theſe portions in being condenſed from the vaporous ſtate, extricated and communicated to the maſs one-third of its heat, and in being frozen one-tenth more. If theſe additional portions were, on the average, only at the freezing point, the original drop muſt have received 2336 degrees of heat, and is ſtill frozen; it muſt therefore, at the beginning of its deſcent, have been 2336 degrees below the freezing point; and its component particles of vapor, as I have before ſhewn, 584 degrees lower, or 2920 degrees below the freezing point *.

But

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* Theſe calculations ſeem amply ſufficient to eſtabliſh the fact here contended for; were it neceſſary, large additions

But the whole heat at that temperature is only 1460 degrees.

HAIL cannot therefore owe its ſolid form to the elevation and general coldneſs of the ſurrounding atmoſphere. It muſt ariſe from ſome cauſe, producing for the moment extraordinary refrigeration in the lower air in which the hail-ſtone is collected. This refrigeration is not the conſequence of the vacuum formed by the collapſion of the vapor into the non-elaſtic ſtate; the utmoſt exhauſtion of an air-pump does not diminiſh the heat of the remaining air above 5 or 6 degrees.

I AM inclined to believe, that the effect is to be accounted for from electricity alone.

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ditions might be made to them. 1ſt, From the original heat of the hail-ſtone, is to be deducted all that which it has received from the atmoſphere in its deſcent. 2d, If any part of its compoſition be ſuppoſed to be an immediate collection of oxygenous and hydrogenous air, we are to deduct from the heat the difference of capacity between aqueous vapor and theſe its component gaſes.

Upon examining the effects of electricity it appears, that heat is generated by it only in one way, by a ſhock or diſcharge [*]. If we charge a phial ever ſo highly, no heat is created. So if a conductor be uſed to carry off the electricity, it receives no heat. Now it is to be remarked, that in thoſe caſes there is no electricity added to the body; the conductor, if perfect, tranſmutes all that it receives, and the electric, in being changed, gives off as much from the one ſide as it receives on the other; or if any portion of electricity be ſuppoſed in thoſe caſes to be added to the conductor or phial, it is only of one ſpecies, vitreous or reſinous. The only way in which we can accumulate both electricities, even momentarily, in any body, is by making it the conductor of a ſhock. While the charge is going through it in both directions, the body contains it in addition to its former electricities. This is alſo the only way in which heat can be generated by electricity; and as the mere paſſage of either ſpecies of that fluid along a conductor gives no heat, we are warranted in concluding that heat is generated by the accumulation of the two electricities. Hence I naturally infer, that a diminution of the electricities muſt diminiſh heat, or produce refrigeration. As I find in a hail ſtorm extreme and ſudden refrigeration, without any other viſible cauſe, the electricity of the atmoſphere being at the ſame time in great pertubation and rapid communication, I am led to believe that hail obtains the ſolid form from the cold produced by the diminution of electricity.

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[*] A ſpark is a ſmall ſhock or diſcharge; the interpoſed column of air is the electric diſcharged by it.

In our limited ſphere of action, we have not even attempted to diminiſh the electricities combined in any body, nor does it appear probable, that we ſhall even ſucceed to any extent in ſuch an experiment. But in the great operations of nature, we ſee conſtant fluctuations in the diſtribution of theſe fluids; and we can ſcarcely doubt that, by various ordinary occurrences, the whole quantity in a cloud or column, if air, may be conſiderably diminiſhed.

But it will be neceſſary to examine more fully the nature of electricity, in order to diſcover the connexion which unites ſo cloſely, ſo inſeparably, all its effects with thoſe of heat.

The prevalent modern theory of electricity ſuppoſes the two appearances of it, before diſtinguiſhed as vitreous and reſinous, to be merely plus and minus quantities of the ſame fluid; at the ſame time it is admitted that every phenomenon may be explained, although, it is ſaid, leſs ſimply, upon the old doctrine; while the advocates of the latter inſiſt, that there are facts which cannot be reconciled to any other principles. It is not my intention here to enter into queſtions ſo fully and ably diſcuſſed, any further than to ſay, that I feel myſelf convinced by the arguments in favour of the old opinion. If upon that ſyſtem, I can account for collateral appearances of nature otherwiſe inexplicable, it will afford conſiderable ſupport and confirmation to the doctrine. I conſider electricity then as diviſible into two diſtinct ſpecies, which may be called vitreous and reſinous. My inveſtigation of the ſubject has alſo led me to conclude, that the union of the two electricities is heat.

In ſupport of this opinion I obſerve,

1ſt, That in every accumulation of electricities there is increaſe of heat, and I have endeavoured to ſhew, that nature preſents appearances of refrigeration to be accounted for only from a diminution of them.

When one column of air has communicated electricity to another, or to the earth, it muſt, upon this hypotheſis, contain a portion of the oppoſite electricity, before combined with that communicated, as heat, but now free and capable of exerting electrical power. If the cloud cannot be immediately ſupplied with an equal quantity of that electricity which it has given off, the decompoſition of the heat muſt diminiſh its quantity and power, or produce cold. In a hail-ſtorm we find ſtrong communication of electricity, and great cold exiſting together; this ſeems to point out the connexion between their cauſes, which I here ſuggeſt. When I conſider that rain is generated in greateſt quantities very near the ſurface of the earth, where it can receive little change of temperature in falling: that its temperature is generally equal, ſometimes lower than that of the atmoſphere; although its component particles of vapor, part of the ſame atmoſphere, muſt have been raiſed more than one-third in temperature, by being condenſed into the non-elaſtic ſtate; and when I at the ſame time find that there is in every ſhower conſiderable loſs of electrical equilibrium, I conclude that rain as well as hail is accompanied in its production by electrical decompoſition, and conſequent diminution of the heat; and that this refrigeration is counterbalanced in rain by the heat extricated in its condenſation.

THE air next the ſurface of the earth is daily heated, and riſes, yet the upper atmoſphere is always cold; what becomes of this heat? The air itſelf is incapable of communicating heat between its particles; the formation of vapor and precipitation of rain, inſtead of cooling the air muſt increaſe the heat by that extricated in their condenſation. The heated air muſt therefore remain for ever heated and elevated, and the whole higher atmoſphere become by degrees intenſely hot, unleſs the heat could eſcape by decompoſition into the electricities. Accordingly, after a long ſeries of hot and dry weather, the atmoſphere is always found ſtrongly charged with free and active electricity.

2dly. ELECTRICITY is generally, if not always affected, the equilibrium is either deſtroyed or reſtored by heat. In exciting an electric by friction, we find that no electricity can be obtained, unleſs there is another body to impart it, or to extract it from the earth. But heat alone gives either electric fluid to the body to which it is applied. Therefore theſe fluids muſt be contained in the ſubſtance conveyed to the body in the ſhape of heat.

THE proceſs by which the communication of heat electrifies any body, may be explained thus: I before endeavoured to ſhew, that all bodies divide the electricities between their different particles. As heat is found only in combination with denſer matter, I ſuppoſe that its production is the effect of the attraction of matter thus combining or connecting the electricities in alternate arrangement. The quantity of ſenſible heat obtained from any quantity of abſolute heat, or of the electricities thrown into the body, is proportioned to the attraction and admiſſion which it preſents to them, and the compleat and perfect union in which it holds them. The degree of combination does not, however, depend upon the cloſeneſs of the approximation of the electricities; for a charged phial, an electrified bar, or any other body whoſe electricities are ſeparated widely by external means, continues to produce the ſame ſenſible heat. It is ſufficient if the body continues to hold the electricities in attraction, ſo that each portion of the one ſhall ſtill correſpond to the ſame quantity as before of the oppoſite. When an increaſe of heat excites electricity, I conclude that the heat or electricities newly added, have arranged themſelves in larger intervals, like the charging a phial, or electrifying a bar.

3dly. THE ſame inference may be eſtabliſhed, by tracing the identity of the effects of friction upon heat and upon electricity.

WHEN an electric is rubbed with a proper rubber, it ſeparates the electricities preſented, retaining and conveying to other bodies that which it is beſt fitted to imbibe. In this operation the ſurface of the electric, and the rubber analyzing the electricities, and being then ſeparated, that part of the electric communicates to the conductor the electricity thus acquired, while another part of its ſurface is brought in contact with the rubber to perform the ſame. If the rubber has communication with the ground, it immediately attracts ſufficient electricity to ſupply the continual demand of the electric.

If a ſmooth glaſs globe be excited by the common rubber, it ſhows vitreous electricity; a rough globe reſinous. If half the globe be ſmooth and half rough, each will be electrified. If a conductor be applied to both parts, and they are equally and oppoſitely electrical, it cannot receive or convey either electricity. Inſtead of two parts, let us divide the globe into infinitely ſmall and numerous particles, having alternately oppoſite tendencies to attract electricity from the rubber; each particle will in paſſing attract its own; the reſult of the mixture is heat. This ſeems to me to be exactly the common proceſs of the generation of heat by friction.

I HAVE deſcribed bodies as having coheſion, in conſequence of their particles tending to analize or ſeparate the two electricities; non-electrics are thoſe bodies which are little capable of dividing theſe fluids into regular diſtinct maſſes, but where each particle preſented to external objects is differently electrical from the next, ſo as to counterbalance each other. In theſe each particle, when excited by friction, muſt, like the ſmooth and rough particles of glaſs, attract its own electricity from the rubber; accordingly the effect of the friction is heat.

To this it may be objected, that if the fluid were attracted from the rubber in the ſhape of heat, it muſt, during the proceſs, diminiſh the temperature of the rubber or bodies from which it is communicated; and that if it were attracted as electricity of both kinds, it would require electric conductors.

THE objection may be anſwered by conſidering the nature of the electrics or non-conductors. Electrics are thoſe bodies which are capable (probably from the regular arrangement of their particles) of ſeparating the electricities into regular diſtinct maſſes. This is, however, an unnatural and forced ſtate of the body, and even in electrics *per ſe*, an addition of extraneous electricity is equally unnatural; accordingly, all electrics reſiſt the being charged, or having their electricities ſeparated; and the force of the electric ſhock is the proof and criterion of the ſtrength of their tendency to return to the equilibrium. The application of foreign electricity having the effect of producing this regular ſeparation of the electricities in the electric, its approach is reſiſted by the coheſive force of theſe fluids already combined in the body. But if by any means we preſent to it equal portions of the two electricities, theſe counterbalancing, and, as it were, neutralizing each other, will not create in the body any electrical tendency, and of courſe the reaſon of its repelling each ſingly does not ariſe. All bodies muſt in ſuch a caſe become perfect conductors. This happens in the production or attraction of heat. The electricities preſented being in the ſame ſtate with thoſe in the body, balanced and neutralized, paſs along without diſturbing the electrical equilibrium, and therefore without reſiſtance.

The natural tranſmiſſion of heat from one body to another is ſlow; but if a ſuperior force is mechanically created by friction, we find the heat attracted ſo rapidly and powerfully, and with ſo large a field of action, that the bodies immediately adjoining are ſupplied as faſt as they communicate it, and experience no ſenſible refrigeration. This attraction, or apparent creation of heat by friction, has hitherto received no ſatisfactory explanation, and forms the principal or only obſtacle to the admiſſion of its exiſtence as a ſubſtance. I reſolve this effect into the attraction of its component parts, each of which is well known ſeparately to have this quality.

4thly. It may even be maintained with reaſon, that heat is only known to us by effects purely electrical, attraction and repulſion, under which are ranked their various modes of action, elaſticity, expanſion, combuſtion, and other combinations. The difference ſeems therefore to be this: when the electricities are ſo ſeparated, and the communication is by ſuch bad conductors, that the attraction of each, for the material object to which it is attached, overcomes their tendency to re-unite, they are eaſily ſeparable, and become free and transferrable ſingly. When they are ſo cloſely united, that the one cannot be wholly ſeparated from the other by the common force of the attraction of matter, they paſs from body to body in equal proportions, and although, in truth, each continues to exert electrical force, yet the minuteneſs of their ſeparation leaving no outward trace of their diſtinct natures, and no tendency to motion being exerted by their attraction, they appear to neutralize each other as electricities, and obtain the name of heat.

5thly. WE obſerve ſo ſtrong a ooincidence in all the habits of heat and of electricity, that Philoſophers have never doubted of their affinity. The generation of light, their common offspring, ſeems alone ſufficient to eſtabliſh the connexion between them. I ſhall, in the ſucceeding pages, endeavour to ſhew, that that phænomenon perfectly accords with the explanation here ſuggeſted of their common nature.

6thly. UNLESS we adopt this theory, we ſhall find ſeveral appearances of theſe fluids which contradict the general maxims of our experience, and every idea which we can form of matter. We ſee heat and the two electricities, by turns ſtart ſuddenly into being, or vaniſh without leaving a trace perceptible to our ſenſe, or exerting any energy in proof of their exiſtence. By admitting their identity, we bring them under the general laws of matter. Its properties may change the direction of their action, but the ſubſtance is always palpable. Two equal and oppoſite motions deſtroy each other ; hence we conclude, that motion is not a ſubſtance, but a quality of other ſubſtances, which may ceaſe to exiſt without injury to the eſſences of the body. The electricities, when ſeparated, are mutually attractive, and therefore a motion, or tendency to motion, is produced; when they are as near as they tend to continue in the body to which they are attached, the attraction no longer produces motion; but the ſubſtances continue to exiſt under the name of heat.

If theſe reaſons warrant the inference that heat is the combined effect of the two electricities, we ſhall find in it an explanation of many of thoſe phænomena which I have before noticed.

Upon the change of any body from the ſolid to the fluid, and afterwards to the gazeous ſtate, the capacity is increaſed, the temperature falls, or heat appears to be abſorbed; at the ſame time the arrangement of the electricities is evidently changed, each particle ſeeming to center the whole of its attraction within itſelf. This in non-elaſtic fluids merely deſtroys the tendency of the particles to cloſe and firm contact, and leaves them mutually in an electrical equilibrium or indifference, except ſo far as they are acted upon by the attraction of cohesion

heſion, of which I ſhall preſently ſhew the nature. The ſolid body when heated, not having ſufficient power to retain the increaſed electricities in ſuch cloſe combination throughout, that attraction which connected the electricities of the ſeveral particles in ſolidity ceaſes to be produced. The whole attraction or combination of the electricities being thus reduced, their effect in the production of heat muſt undergo a ſimilar diminution. This ſeems to be the reaſon of that increaſe of capaeity and apparant abſorption of heat, which we perceive upon the change from the ſolid ſtate. When the body is volatilized, the internal attraction which held each particle together, is alſo deſtroyed, and the ſubdiviſions exhibit mutual repulſion. The combination of the electricities thus receives a much greater diminution, and their effect as heat is proportionably more reduced than in the former change.

Thus we can obtain ſome inſight into the nature of that combination of the electricities, which moſt powerfully produces heat. I have before ſhewn that it does not depend upon the cloſeneſs of their approximation, nor upon their being in larger or ſmaller maſſes. It depends upon the arrangement of oppoſite and attractive portions of electricity alternately in every direction, without any repulſive or non-attractive ſurfaces ever adjoining.

Hence it is that the general increaſe of bulk of bodies by heat, and increaſe of ſize of water by cold at a certain temperature, unaccompanied by a change of form, or of the arrangement of the electricities, has no effect on the capacity of the body.

Upon the ſame principles we may, perhaps, account for ſome of the moſt conſpicuous differences in the modes and effects of combination of bodies. In ſome compounds the capacity is increaſed, in others diminiſhed; ſome are fuſed or volatilized at a lower temperature than their components, others at a higher. Some combinations are nearly permanent, others yield to the firſt change of temperature; or to the attraction of other bodies. Theſe varieties ariſe from the different modes of attraction binding the bodies in union. The heterogeneous particles may tend to divide the electricities between them either partially or entirely; or they may be attractive by the one body's ſeparating the electricities into wider and larger diviſions than the other. Theſe differences may be infinitely varied, and the effects on the combinations muſt be regulated by them. Thus two bodies in combination, may tend to correct the effect of the heat in electrifying each, and ſo their continuance in combination may be very great. The two bodies have originally only a certain power of attracting or holding in combination the electricities. If by their union the electricities are brought into more or leſs cloſe combination, the temperature and capacity muſt be altered; and as the whole quantity and cloſeneſs of combination of the electricities, no longer bear the ſame proportion to the power of the bodies to contain them, the period of fuſion muſt be proportionably accelerated or retarded.

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SECTION IV.

The appearance of light is ſo intimately connected with thoſe of heat and electricity, that no ſpeculation upon their nature can be entitled to attention, unleſs it include a reaſonable account of this phænomenon. I have found its appearances ſo perfectly to coincide with the opinions which I have above ſuggeſted, as to furniſh a very ſtrong confirmation of their truth.

It is found that all bodies are conſtantly emitting rays, which, when ſupplied in a certain copiouſneſs, affect the eye with the ſenſation of light. The elaſticity of the fluid, or mutual repulſion of particles of ſimilar electricity, ſeem conſtantly exerted to effect its eſcape from the poiſon which the groſſer matter throws around it. Theſe rays I take to be in all caſes particles of ſingle electricity, not of heat.

Rays of light are found to travel at a certain equal velocity, and calculations of their quantity and velocity have ſuppoſed each particle of light in a ſun-beam, minute beyond our conception, to be diſtant about a thouſand miles from its ſucceſſor in the ſame direction. This accounts for their ſhewing little electrical attractive force, their velocity being too great, and their bulk too minute to allow its action upon heavier bodies.

If a ſubſtance emits viſible rays of each of the electricities, as muſt happen where it is rendered luminous from equal increaſes of each, that is from heat, their re-union in any body which ſtops them will re-produce heat. This re-union may, however, be prevented by making the rays paſs through a medium which will tranſmit the one ſpecies of electrical particles, and abſorb or reflect the other. Thus the rays of a common fire, collected in the focus of a concave mirror, give great heat and light. If a piece of glaſs be interpoſed, the focus exhibits great light, but no heat.

The ſolar rays ſeem to be emanations of ſimilar electricity, for when ſeparated they produce effects ſimilar to each other and to the whole, varying only in ſtrength. If they conſiſted of oppoſite electricities, any body which ſtopped their courſe, however ſituated or of whatever texture, muſt receive equal heat from them; but in fact the air receives hardly any heat from the ſun's rays, and mountains, and even elevated continents, much leſs than lower grounds. I ſuppoſe the difference to ariſe from the degrees of facility, with which different bodies can ſupply the oppoſite electricity, to be combined with the ſolar rays in the formation of heat.

As the electricity of the earth has attraction for the whole maſs of matter of which the globe conſiſts, the general direction of this force muſt be towards the center; it muſt, therefore, exiſt in greater quantities at the level of the ſea, than in places removed above the general ſurface. Bodies thus ſituated can, therefore, afford a ſmaller ſupply of this electricity to be combined with the ſolar rays into heat. Elevated regions, however level or extenſive, are therefore much colder than others in the ſame latitude, lying lower.

Although the minuteneſs of particles of light prevents them from occaſioning perceptible electrical ſenſations in the bodies upon which they fall, yet their electrical power is not inactive; it is unable to move the groſſer body, but its effect on the lighter ſubſtance of the ray is very ſenſible. In paſſing from a thin to a denſe medium, the rays are attracted by the latter moſt ſtrongly, and are therefore refracted. Their various refrangibilities ſhew that this effect ariſes from their particular attractive tendencies, or electrical forces, not from any general gravitation of matter.

If a capillary obſtacle is placed adjoining to the path of a ray, the latter, inſtead of being attracted to the material object, is repelled on each ſide, and deflected from its courſe. This is is an effect merely electrical; it is produced thus. All bodies are more or leſs electrics. The ray acts like any other portion of foreign electricity, tending to charge the body by diſturbing the equilibrium or natural arrangement of the electricity within it. Its approach is therefore reſiſted, and the ray repelled and deflected. The reſiſtance of all ſurfaces to admiſſion of light, is probably the cauſe of opacity, or of the abſorption or reflection of light, from the multiplicity of ſurfaces of the particles of opaque bodies.

If a plate of one tranſparent medium be interpoſed between two others of a different denſity, regularly diverging; as if two plates of glaſs, the one a portion of a ſphere, the other a plain, joined in one point, have the reſt of their ſurfaces ſeparated by air, and a ray be made to fall upon the plates, it will be alternately tranſmitted and reflected from the lower ſurface of the interpoſed medium in a regular ſucceſſion of colors, according to the thickneſs of the interpoſed plate of air. If the experiment is tried with a ray of one color, it is alternately tranſmitted and reflected at regular increaſes of thickneſs of the interpoſed medium. This is according to the common laws of electricity. If a bar is electrified, or charged by the application of foreign electricity, its electricities are ſeparated into maſſes alternately vitreous and reſinous, the ſpace occupied by each, or the ſize of the diviſions, depending upon the force of the electricity applied. A magnetic bar exhibits the ſame phænomenon. The plate of air, penetrated by the ray of light, repreſents ſuch a bar, which is charged, or ſuffers a ſeparation of its electricities by the application of the foreign electricity, the ray. If the length of the bar, or thickneſs of the interpoſed plate of air, be ſuch that only one diviſion of the electricity with that ſtrength of charge can be contained in it, that will neceſſarily be of the ſame kind, vitreous or reſinous, with the ray or electricity applied. A repulſion muſt, therefore, take place between the ray and the medium, and it will more readily paſs on to another tranſparent medium than revert through this. If the medium be of ſuch thickneſs as to admit of two diviſions of the electricity, the one ſimilar to the ray, the other oppoſite, the latter muſt be attractive to it; and therefore when the obſtacle of another ſurface, the lower plate of glaſs, is oppoſed, and the ray is alſo attracted by the medium in which it is moving, it is ſtopped in its courſe and reflected. The third ſpace is as the firſt; the fourth as the ſecond; and thus the alternate fits of eaſy tranſmiſſion and reflexion ariſe. The rays of different colors having different electrical powers, produce various intervals or diviſions of the electricities, and therefore are reflected at different thickneſſes of the medium; hence the ſucceſſion of colored rings from a white ray. The alternate attraction and repulſion between the body and the ray, and the conſequent contraction and dilation of the former, may create the effect of vibration, to which Sir Iſaac Newton attributed this, and almoſt every other phænomenon of the ſolar rays. This vibration may aid the proceſs.

In theſe caſes I ſuppoſe the effect to be produced by the bodies being electrified, or having its electricity arranged in an unuſual manner, by the application of extraneous electricity. But I have before ſhewn; that all bodies at reſt contain the electricities ſeparate and diſtinct from each other, although leſs widely removed than when electrified; and every appearance of electricity marks it as an eſſential principle of its nature, to arrange itſelf in each body in diviſions perfectly regular. Bodies even at reſt may, therefore, be conſidered as repreſenting an electrified bar, conſiſting throughout of regular diviſions, alternately vitreous and reſinous. This arrangement will extend as far, as there is a continuation of matter ſufficiently ſimilar in denſity to carry on the alternate fluctuation of electricity unbroken. Where two ſuch bodies are ſo nearly in contact, as to communicate and link toge- the electrical chain, a certain attraction muſt take place between them. This is the attraction of coheſion.

All bodies being thus arranged in regular diviſions of electricity, the next inquiry is what thoſe diviſions are. The nature of electricity will explain them.

If light be electricity, this is a generic name for many fluids, varying in refrangibility or attractive force. The ſolar electricity is ſeven-fold; the oppoſite is alſo varicolored, and I ſhall preſently endeavour to ſhew, that it muſt in every thing correſpond to the ſolar. There is nothing to lead us to believe, that the various colors or ſpecies of ſimilar electricity have any union or attraction among themſelves, or are otherwiſe connected, than as their ſimilar tendencies produce ſimilar, and therefore apparently joint effects, from the confuſion and imperfection of our obſervation. Whenever their natures differ, we find each produce its effects ſeparately and independently. The ſame variety of electrical force which cauſes the difference of refrangibility, and which produces the colored rings from a white ray, piercing a plate of air between two ſurfaces of glaſs, muſt cauſe the ſame difference in the intervals at which the various electricities are arranged in bodies at reſt, the moſt refrangible, or thoſe of greateſt electrical force, having the greateſt intervals or diviſions.

ſions. In elaſtic bodies, as the atmoſphere, where the groſſer matter is thinly ſcattered through the maſs of electricity, this effect muſt be moſt ſtrong.

The truth of this reaſoning ſeems to be eſtabliſhed by attending to a very ſingular coincidence in nature, hitherto not ſatisfactorily accounted for; the exact proportion between the refrangibility of the colors, and the notes of a muſical octave; the moſt refrangible correſponding to the deeper notes or larger vibrations of the muſic. It is impoſſible to believe that this coincidence is accidental, and the rules of philoſophy compel us to conclude, that the ſame power produces both the effects. I ſuppoſe it to reſult from the arrangement of the electricities in the air, according to their colors or refrangibility.

A sound is the vibration of the air, carried along by the elaſticity of the electric fluid in regular undulations, which may be conſidered as artificial diviſions of the atmoſphere. Its natural and permanent diviſions are thoſe produced by the arrangement of the differently colored electricities. When the vibration or artificial diviſion coincides in ſpace with any one natural diviſion, or any regular number of intervals of one electricity, the ſound or vibration will be regular, even, and melodious. This is a muſical note. If the vibration be increaſed in length, ſo as to include the ſame number of intervals formed by the next color in frangibility, the next muſical note is ſounded. When the vibration is increaſed ſo as to include double the number of intervals of the ſame electricity as the firſt, the octave of the firſt note is produced; being performed by the ſame electricity, the ſounds are perfectly homologous *.

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* Probably the intervals or diviſions of the electricities in the air are very ſmall, and there may be many ſuch in every artificial diviſion by a muſical vibration. The different numbers of thoſe intervals in each vibration, probably mark the diſtinction of the different keys in muſic. The key A, may contain 9. 18. 36. &c. the key B. 8. 16. 32. &c. of the natural diviſions in each vibration. Thus

LIKE every other material object, the eye and optic nerve muſt be filled with electricity, ſeparated into diviſions alternately vitreous and reſinous, of each color, and muſt be ſuſceptible of having their electricity excited, or arranged in a new and unuſual manner, by the application of foreign electricity. Hence we muſt conclude, that

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the ſame note may coincide with different keys. For if a vibration include 8 diviſions of one electricity, it will alſo coincide with 9 intervals of another, whoſe refrangibility is to that of the firſt, in the proportion of 8 to 9, and ſo be in harmony with a key including 8, or with one including 9 natural diviſions in each vibration. From the number of different colors by which any ſound may be carried along, probably ariſe the diſtinctions of flat and ſharp notes, and all the varieties in harmony.

The refrangibilities of the different colored electricities are in certain proportions which will correſpond at the following intervals. The violet, the moſt refrangible, will include in 9 of its diviſions, 8 of indigo; in 5, 6 of blue; in 3, 4 of green; in 2, 3 of yellow; in 3, 5 of orange; in 9, 16 of red; in every diviſion, two of its own octave. Men acquainted with muſic may, perhaps, carry very far the inveſtigation of the conſequences of theſe coincident proportions upon harmony.

the differently colored rays muſt operate upon the optic nerve according to their refrangibilities or electrical forces, ſeparating its electricity into diviſions of various dimenſions. This different arrangement, and conſequent various tenſion of the nerve, is probably the origin of the ſenſation of color, and therefore of all viſion. Accordingly, we find that any other electrical affection of the optic nerve, as the application of common electricity, or of what is called animal electricity, produces the ſame ſenſation with light. The ſame effect is imitated by a blow or preſſure upon the eye, expanding or contracting the nerve.

THIS explanation of the nature of viſion, and the ſenſation of color, will account for the exact, and evidently more than accidental coincidence in the different colors of the oppoſite electricities. For as electricity of any color is in its diſtribution alternately vitreous and reſinous, the one of theſe muſt occur in the ſame ſpace as often as the other, and produce equal diſtribution of the electricity of the eye or other body upon which they act; this muſt produce equal arrangement and tenſion of the optic nerve, in which I ſuppoſe all ſenſation of color to conſiſt. It is therefore ſcarcely material to inquire, whether the oppoſite electricities are naturally divided into ſimilar colors or ſpecies mutually correſponding in force, or whether the one only is ſo divided, and the other is compelled by attraction, to aſſume the ſame arrangement to correſpond to and balance each diviſion of the firſt. The effect muſt be the ſame upon either hypotheſis.

I HAVE thus endeavoured to trace the general outline of connexion between heat, light, and electricity; and hope to have ſhewn that the two former are only different actions of the latter power. It were beſide the purpoſe of this eſſay, already ſufficiently multifarious, to examine the abſtract cauſes of that attractive force of electricity by which theſe various phænomena are produced, and to explore the whole properties and effects of this wonderful fluid. To follow it in all its ſhapes, and ſcrutinize all its operations; to trace it as the general parent of attraction, producing that gravitation which arranges the univerſe into order, and giving, by its balanced force, that *vis inertiæ* which ſeems almoſt the eſſence of matter; to paint it as the moſt powerful, moſt univerſal agent of the Almighty Creator, is for me too arduous a taſk. We know not how far the induſtry of future ages may raiſe the ſtructure of human knowledge. My ambition is ſatisfied, in hoping that I have added one ſtone to the fabric, or arranged and cemented ſome looſe and confuſed materials of the pile.

FINIS.

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SIX LETTERS

ON

ELECTRICITY.

BY THE

REV. WM. JONES, M. A. F. R. S.

LATE RECTOR OF PASTON, IN NORTHAMPTONSHIRE, AND
MINISTER OF NAYLAND, IN SUFFOLK.

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LETTER I.

DEAR SIR,

IN the natural world, a scene so new and extensive has been opened by the late discoveries in Electricity, that it is not easy to assign a reason why they have been so little applied in philosophy. The leading facts in this science rose up at a strange time and in a strange manner; as if they were intended to be of great use to the world; which use hath not yet appeared, though the science hath been in the hands of very ingenious men. Of the time at which Electricity was discovered, I say nothing as yet, though it was very remarkable: the manner I can relate to you nearly as I received it thirty years ago from an intimate and respectable friend, who was a party concerned in the discovery, the late Reverend *Granville Wheler*, of *Otterden Place*, in *Kent*.*

There was an ingenious man, Mr. Stephen Grey, a pensioner of the Charterhouse, who delighted much in experiments. It was the practice, at that time, to rub a large tube of glass for attracting threads and other light bodies; and Mr. Grey having found that his tube would not act well but when perfectly clean and free from dust, stopped the open end of it with a cork. One day, when he had rubbed his tube and applied a thread to different parts of it, he observed that the thread went to the cork at the end as readily as to the glass of the tube. This taught him that the power of Electricity was communicable from glass to other bodies. The steps he made, in consequence of this, were easy and natural. Instead of the cork, he fixed into his tube the joint of a fishing rod, and discovered the same power to the end of it. At last he tried his whole fishing rod, with a line of packthread and an ivory ball at the end of it, from an upper window; when the ball at the end was still found to attract light bodies as before. With this discovery he went full fraught to his patron Mr. Wheler, in the country, and repeated every thing with success as far as he had gone. But they determined to go farther; and for this purpose repaired to a long gallery above stairs, which encompassed three sides of the house *; and having extended their line, the length of which required that there should be loops from the ceiling to support it, they tried the effect; but now there was no answer, and they were quite at a stand. But it so fell out, that they blundered upon a true method in consequence of their own false reasoning. These loops of ours, said they, are too thick and too heavy, (for, by the way, they had made a trial of iron wires;) our way will be to make the loops of the strongest line we can get, with the least

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* He was commonly called by the name of the *Reverend Granville Wheler Esquire*, and is addressed under this title by the ingenious Mr. *Benjamin Wilson*, who dedicated his Treatise on Electricity to him. He was the son of Sir George Wheler, Knight.

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* This ancient seat, which had an observatory at the top of it, has been pulled down to the ground for some years.

weight and substance. On this consideration they gave the preference to sewing silk; and now all was right at once: but they still argued, that their success was owing to the smallness of their lines, not to the silk of which they were made. A few more experiments taught them to correct the mistake; and they discovered, that there were bodies of different constitutions, some of which would stop the power, while others would let it pass off freely and be dissipated: these we now call *conductors*. Thus the great distinction was opened between Electrics and Non-electrics. But every thing came out by accident: for Mr. Wheler assured me, that neither he nor Stephen Grey had ever reasoned right in any one instance that he could remember; so contrary were the effects of Electricity to all the pre-conceived notions of Philosophers.

Mr. Hauksbee, an ingenious operator to the Royal Society at the beginning of this century, invented a method of increasing the power of glass, by mounting a globe so as to be turned by a wheel: and a globe being so contrived, as to be capable of being exhausted of its air upon an air pump, the electric Fluid began to display itself in a wonderful manner. Opaque bodies, when illuminated by it within the globe, became transparent; for when the inner surface of the glass was coated with pitch or sealing-wax, the hand of the operator, which rubbed the globe, became visible through each of these substances.

Both Hauksbee and Grey shewed a disposition very early to speculate upon their new experiments, as if they had discovered in them some alliance with the great moving powers in the System of the World. Grey was delighted with the prospect: but in the application of his experiments he was rather too hasty, and his haste made him inaccurate; of which the Philosophers of the time, who had then lately set their whole affections upon a *vacuum*, took advantage to render his speculations inconsiderable: and with many practitioners the electric medium still kept the name of an *effluvium*; as if it had been emitted wholly by the glass, and were of little more account in the world than a common odour.

In a short time it came to pass, by another singular accident, more remarkable than that which had happened to Stephen Grey, that Muschenbroek of Leyden discovered a new force, of which, from that time to this, it has troubled the learned to give any rational account; opinions being even now in agitation concerning it, which are in direct opposition to each other. Electricity had hitherto appeared as a simple direct force, which could make its way through iron as easily as through a vacuum. But now there came upon the stage a new force which we may call *reverberatory*; because the Fluid, instead of flying off forwards, as in common cases, is arrested, retained, accumulated; and flies back again with a great stroke and an explosive noise. Muschenbroek had suspended a glass phial of water at his conductor, and was electrifying it to try how long the water inclosed by the glass would retain its electricity: but, in doing this, he grasped the bottle with one hand to remove it, while his other hand touched the conductor, and in this instant he received a stroke through his arms and breast, attended with such a sensation as no man had ever felt before, and which he that has once felt will never forget. This was a wonderful fact; and as soon as Muschenbroek had made himself master of it, he reported it. The fame and the practice of it soon flew into every civilized part of the world. People of both sexes, and of all ages and conditions, repaired in crouds to see and receive this wonderful shock; and the public curiosity was so much awakened, that every body was ready to hear what writers had to say upon the subject. Dr. Watson, a physician, gained great reputation by his manner of treating it, and I heard several learned persons pronounce his work to be the best that appeared upon the occasion. He made no scruple to call the new power of Electricity by the name of *Elementary Fire*, and his electrical machine a *Fire-pump*.

It is something remarkable, that from the earliest days, when excited amber and glass were first observed to crackle and flash in the dark, an alliance was suspected between this Light and the Lightning from the clouds: and, in process of time, when the matter came to a trial, this alliance was no longer doubtful. Which of the two was first in bringing down fire from Heaven; whether *Romas* of France, or *Franklin* of America, has not been well ascertained, so far as I have been able to learn: but let it be Dr. Franklin; for then the fact will be an ominous prelude to the business he was soon afterwards to do in the world, in drawing down the fire of civil war upon his country, and spreading the confusion of anarchy over the earth. The Frenchman may certainly put in his claim; for the omen will agree as well with his present national character: but we need not trouble ourselves in settling their respective shares: they have it all between them; there being no others who have so just a title as the American and the Frenchman to be called the Incendiaries of the world.

Philosophical men became so fond of this new art, whereby a thunder-cloud was turned into an electrical machine, that the practice became common, I think, rather too common, in many places. A poor Professor of Petersburgh was at this work, when a ball of fire came suddenly down from a cloud into his machine; and he being the nearest object to his conductor received the stroke upon his forehead, and was killed upon the spot. When I read of this fatal accident, my mind is shocked with it, and I am reminded of that day, when the boldest Philosopher shall discover, with this unfortunate Professor, that Heaven is not to be trifled with. But Dr. Priestley discovers him to have been a very fine man, and that he died a very fine death, such as other Philosophers might envy and desire. His notions and mine differ very greatly on many subjects; and his reflection on this occasion must arise from some new theory of life and death, worthy of Dr. Priestley.

The relation between Lightning and the Electric Fluid being established, it was inferred, that lightning might be collected and dissipated without mischief: and no house was thought to be secure without a conductor upon the top of it. But the caſe is attended with difficulties, as time hath shewed; and the argument in favour of knobs against points is a sufficient proof of it. At first the whole dependance was upon the effect of sharp points, to draw off the matter of lightning by a silent discharge. But points having miscarried in the caſe of the powder magazine at Purfleet, there arose a serious dispute in favour of the ball or knob against the point; it being objected that the point was more apt to invite the flash, and less apt to disperſe it. I am not clear how this ought to be; and I question much whether we are competent to the stating of it. This I know, that from the beginning I never was very sanguine in favour of the conducting plan. The following accident discouraged me very early. I knew a place in the country, where there is a high steeple of stone, with an iron spindle and weather-cock at the top: but when a storm of thunder came over, the lightning struck a low house not far from the church, which house it burnt to the ground, and killed some people within it; while the church, a much higher building, was untouched. This taught me, that the conducting principle was not to be depended upon, if a high pointed building near at hand had proved no security to a low one. I knew of two houses afterwards which were struck while they had conductors of iron upon them. There were not wanting persons on this occaſion, who argued as if they had found out, that the conductors had not acted properly on account of some defect: but these things served to convince me, that there were dangerous difficulties in the way; that conductors did not act quite according to the theory, or that their effect, whatever it may be, extends but to small distances; that in certain cases they may even be attended with danger. What escapes St. Paul's church and the magazine at Purfleet may have had from the lightning itself, we know not, but we have much reason to believe that they have had two escapes from conductors: and, on these considerations it has appeared to me of late years as a matter of no great consequence to *inoculate* buildings against lightning. It is a good thing if we can lessen the danger of ships at sea by it, and we may be thankful for the discovery.

Since this invention of drawing fire from heaven, improvements have consisted chiefly in playing new tricks, and diversifying old experiments, and observing how minutely various the states of bodies, and of the atmosphere with its meteors, are, in respect of their electrical affections. Here the science is without end. How much more easy it is to multiply than to simplify! When old things appear to us under a new shape, we give them new names; and when we get new names we think we get new knowledge. Hence hath arisen a vain expectation, that if we do but wait long enough, experiments may be increased, till it will be time to raise a Theory; but that time, I fear, will never come: so far as the purpose of a theory is concerned, materials are very nearly in the same state now, as they were fifty years ago; and we are now most certainly in a state to do something, if there is any thing to be done. Our information has proceeded from a quarter whence we had very little reason to expect it. Electricity, so called from *Electrum*, *Amber*, began with moving a straw; but hath now shewed itself powerful enough to move the world; and being such, it is intitled to some great share in the œconomy of it. If it acts for *evil*, as in lightning, it has the same ability to act for *good;* and for great good the Creator undoubtedly intended it. Such observations as I have made, with a view to discover this, I shall freely impart to you; and I think I have already said enough in this letter to raise your curiosity. If Pliny the natural historian had been told, that there was a man in Britain, who could send a strong spark of fire out of brass into another man's forehead, which should strike without burning, and come out instantly at his toe, he would not have rested till he had learned all that could be known of the secret. Such a wonder as this has been reserved to our days; and now we have it, you will think, as I do, that if we can, we ought to make some use of it in our philosophy. With this design, I shall take the liberty of addressing some future letters to you: And am,

With sincere affection,

Your very faithful humble Servant,

January 3, 1797.

LETTER II.

SIR,

AFTER the general view of things, which I gave you in my former letter, we must now descend to particulars; and ask, *what* it is that *acts* in Electricity? This is the first question which any curious person will ask, who has heard there is such a thing as Electricity, and seen some of its wonderful effects. And here, instead of giving you a short answer, I shall set before you some plain facts, which will be sufficient to prove, that the causes which act in Electricity are not new, but very common and familiar to us; and that we cannot deny them without denying our senses.

When a person electrified presents the point of a sword to you, you feel a blast of air from it very sensibly; and to convince yourself that this is no deception, let a bason of water be placed upon the ground, and let the point of the electrified sword be presented downwards near to the surface of the water, the blast from the point will make a dint in the surface; and the same, being directed toward the flame of a small lighted taper, will blow it out. If any doubt should yet remain (for some plain things require a great deal of proving) let us appeal to the air-pump. Place a vessel of water under a glass receiver, and point an electrified wire toward the surface of the water as before, the dint on the surface will appear as it did from the sword; but exhaust the air and the point will now make no visible impression. Therefore that impression was made by the matter we have exhausted; and that matter being air, it appears that air is an agent in our electrical experiments. It is farther worthy of observation, that light bodies, which are attracted while the air is in the receiver, are not attracted in vacuo: for hence it must appear, that whatever the manner may be, after which the air may act or be acted upon, it is necessary to the effect. This was observed and affirmed by one of the first operators in the science, an ingenious man to whom we are under great obligations, I mean Mr. *Hauksbee*. He was of opinion, that in the case of an attrited globe or tube, " the external " air is necessary to *carry* the little bodies which *we* " *say are attracted* towards the tube. For if by the " heat and rarefaction consequent upon the attrition, " the medium contiguous to the tube be made specifi" cally lighter; then of course to keep up the balance, the " remoter air, which is dencer, must press in towards the " tube, and carry away the little bodies lying in its way " thither also."* Dr. *Priestley* wrote a ponderous book, which he calls a History of Electricity; but he is not a man from whom we should expect either a fair account or a judicious performance. He pretends to give an account (and a confused one it is) of *Hauksbee* and his experiments; but says not a word of this his idea of electric attraction. *Priestley's* book appears to have been compiled with a factious intention, which tempted him to suppress, or magnify, or depreciate, as he should find occasion; that he might keep the science as much as possible within the few hands of himself and his party. Mr. *Hauksbee's* was a rational conjecture for the time, and near the truth, but not quite accurate. Electric attraction is still a subtile phænomenon, which will be imperfectly understood after all our trials. I can see that more are wanting even at this time of day; and there is one circumstance relating to it, which is very remarkable: that although the power of Electricity be an *effusion*, working *outwards* from the machine, the *first* motion of bodies is *inwards* toward the machine, they being universally attracted before they are repelled; which being a fact of great consideration, I shall have something particular to say upon it in another place.

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* See his Experiments, p. 244.

Experiments teach us farther, that the electric Fluid is the same with that which gives *heat* to bodies. Of this I was once in some doubt, having found that a thermometer was not affected by its motion; whence I supposed that a fusion of metal by electric force might be a cold fusion, as had been reported of fusions by lightning. I therefore desired a friend, whose apparatus was very compleat, the late ingenious Mr. *Henley*, F. R. S. to shew me the capital experiment for this purpose by exploding a small wire, and catching some of the liquified sparks upon a sheet of writing paper, which he did accordingly; and a very fine shower of fire flew about the room, the sparks of which appeared to have scorched the paper in several places, as any other fire would have done. We now understand, that when the electric Fluid is *compressed,* by being forced through too small a channel, it then acts as fire: bodies are violently *heated* by it, and even melted with a burning fusion, as we see in this experiment of the exploded wire. A mercurial thermometer also, though not sensibly affected by being electrified in the ordinary way (which was the occasion of my mistake) may be made to rise thirty degrees, if the shock is made to pass through it after the manner described by the late ingenious Mr. *George Adams*: See his Lectures Vol. IV. p. 390. It is certain then, that the electric Fluid gives heat: that it will fire tinder, light a candle, kindle gunpowder, &c. Some philosophers have long supposed, that motion is the cause of heat: so it is; but this happens only because fire is moved. The heat which arises to solid bodies is not immediate in themselves, but in the matter which penetrates and acts within them. This the electric Fluid being able to do, is occasionally excited to the condition of heat, and is therefore one of the modes of fire. That which has the properties and effects of fire, should be called fire, when we speak of it as a Fluid; otherwise we shall have two things in nature, with the same properties, and to serve the same ends, which is by no means agreeable to sound philosophy. It is now time that the late doctrine about fire, which taught that fire is nothing in itself, but that the parts of solid bodies in motion are called fire, should be laid aside, as obscure, unphilosophical, and contrary to experience. I have often wondered at the disposition which has discovered itself in Mathematicians of modern days, to annihilate fire, and turn it into *motion;* though it be without question the universal fluid of the world. *Galilæo* argued, that it was *hitherto doubtful whether there be any such element as fire.*[*]

Instead of producing so many facts, to shew that the electric Fluid is fire, I might have contented myself with referring you to the many authentic accounts, which assure us, that the fire of Lightning and the fire of Electricity are the same, and may be substituted the one for the other; for in that case we have nothing to do, but to prove that Lightning is Fire: and did any body ever doubt it? By an aerial conductor we can take it out of a cloud, and perform the same experiments as when it is excited in the ordinary way by attrition of glass. What we take up in a drinking glass from the ocean is not more surely the matter of water, than what we take out of a thunder-cloud is the matter of fire.

It must have been observed farther, for we cannot help seeing it, that the electric Fluid is luminous and shines as light, the same with that of the sun or a lighted candle. And here again it would be as unphilosophical to allow of two sorts of light in the creation, as two sorts of fire. But I may convince you by an experiment, that the electric Fluid is not only a luminous body, but that it is really and truly the body of light, such as we have always been used to, because it has that property which is characteristic of light. By the refraction of a glass prism, the rays of the sun are separated into seven colours; three of them primary or simple, and four compound. From which I thus argue; that if the light from the sun is thus separable into colours, and the light of Electricity is separable into the same, we are to conclude, they are both of the same matter. The experiment is made in the following manner: We present a non-electric to the conductor within less than the striking distance; in which case a succession of sparks will succeed one another so quick, that they appear to the eye like one continuous line. View this through a prism of glass, and you will see the same coloured spectrum, as if the rays of the sun had formed the object.* Therefore the solar light, and the electric, however they may shew themselves, are the same in kind, as surely as the noise of thunder is the same in kind with the noise of the Leyden bottle. After this, it is hardly worth while to mention, that if you hold up a leaf of gold between your eye and the window, the rays which pass through it are green; and the sparks drawn from gold have the same appearance,

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[*] Dico primum, esse dubium adhuc, an sit Elementum aliquod Ignis. Op. 1635, p. 437.

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* This experiment was published by Dr. Priestley as an original experiment of his own, though it had been published several years before.

If these things are so, let us agree, that the light which Electricity exhibits, is not a new composition, but the old light, which has flowed from the Sun, and flashed in the Heavens, and shone in the Rainbow, from the beginning of the world: and that if it be compared with Lightning, it has the same effects and the same appearances. As the sun which now shines in the Heavens, is the old sun which shone upon our forefathers, so is the light which now shines in Electricity the old light; and we shall not be able to change its nature by putting some new name upon it: its mode of acting is indeed newly known to us, and well deserves to be studied. The wise men of France have put new names upon the days and the seasons; but, God knows, they have mended neither the times nor themselves. They have divided the month into three decads, instead of four Sabbaths: but the moon has her four quarters as she had formerly, and will have them to the end of the world. No whole number will divide her monthly period so truly and properly as the number 7; and they who would change it for a better, should give us a new arithmetic; which, among the rest of their extravagances, I wonder they have not attempted.

I have now answered the question I proposed at the beginning of this letter; and shewed you that the power, which acts in electricity, *blows*, and *burns*, and *shines:* let any man prove, if he can, that it does not. With this, for the present, you will be satisfied; and believe me, dear Sir,

Affectionately yours, &c.

January 6, 1797,

LETTER

LETTER III.

SIR,

THE design of my last letter was to shew *what* it is that acts in Electricity: I am now to proceed a step farther, and inquire *how* it acts. You have seen, that how various soever effects may be (of which there is no end) the causes are such as have always been known. They appear to us under a new character, but they are still the same. We might disguise them by giving them new names: but real knowledge would thereby be rather confounded than improved. When a ship is blown up, you may tell me it is *gunpowder* that does it; and that gunpowder is a composition found out in modern times, and composed of certain ingredients in such and such proportions. But I say, no: I say the ship is blown up by a flash of *fire* and a blast of *air*; and that gunpowder is no more than the *vehicle* in which these powers act. This is a solution of less shew and verbosity: it is embellished neither with *oxygene* nor *caloric*, nor any other term borrowed from the mysterious vocabulary of the new *Capnology*: but it declares, in old terms, the whole secret at once, and is agreeable to truth and fact: as such I am content with it. If you please, you may fill a book with receipts for making, and directions for kindling, and rules for applying the force of gunpowder; and for so doing, I will allow you to be an expert man, and that you instruct us farther in the works of art; but you go no farther into the *causes of Nature* than I do. Their action under the form of gunpowder, and their action upon the stage of Electricity, is such as the world was not formerly acquainted with. They did not foresee, that art would so nearly imitate the force of a volcano, and the action of a thunder-cloud.

But we are now proceeding to a part of the subject, which will oblige me to take a large compass: for when we inquire *how* these causes act, we have a wide field before us, where nothing is to be explained, unless the following doctrine be admitted as a foundation; that in all free spaces, and within the pores of all bodies, whether solid or fluid, there exists a subtile æther or elementary fire, which, while at rest in equilibrio, seems to be doing nothing; but is at the same time silently at work in all nature. Till it is disturbed, or thrown out of its balance, it does not show itself; and even then, we know it not in its *total* force, but only in its accidental *differences*; for its total force is such, that unless it were counterbalanced, it would crush the world.

If there be two equal scales, each of which carry a weight of 100lb. they are at rest: but if you place the weight of half a pound in either of the scales, the one goes down, the other up, but only with this force of half a pound; and if we should conclude this to be their whole force, we should be greatly mistaken.

It is thus with the forces of electricity: we discover them in their differences; but even these on certain occasions are such as are attended with great effects. How these differences are made to appear, I shall explain to you on the principle I have already laid down.

In that ocean of invisible elementary fire, wherein we live and move, we place a machine, and turn a globe or cylinder of glass. When the glass is turned about, the element, in which it revolves, follows it; as when a grindstone turns in a trough of water: and so long as the revolution of the fluid is uninterrupted, nothing is done; whence we might ignorantly conclude, that the glass revolves in nothing. But if we apply a cushion to the surface of the glass, and make a stoppage or dam, the medium, which could before flow freely, is now separated into two conditions, and consequently put out of its natural state. Part of it can pass the cushion, and part of it cannot. To the cavity within the glass none of it can escape; because glass is a substance through which it cannot pass freely, being partly hindered by the air incumbent on the inner surface of the glass, and partly by the structure of the glass itself, which is of such a constitution as not to admit it. The fluid therefore which surrounds the glass and moves with it, cannot be as it was before: it is stopt by the close contact of the cushion, and as it were *strained* into a new state; I say strained, for I believe this circumstance to be a chief part of the secret. When Electricity first came into observation, it was natural to imagine, that the effect was excited by an *attrition* of the rubber upon the surface of the glass, either working upon the *air*, or putting the parts of the glass into an unusual agitation, so as to make them *emit effluvia*, &c. But farther experience shewed another thing: for if the separation takes place, the attrition is of little consequence. A rubber of a proper length, though it were but a line in breadth, would answer the purpose, provided the contact between that and the glass be as perfect as possible; which is greatly promoted by rubbing over it an amalgama, or mixture of zinc and quicksilver about the consistence of an unguent: or some *aurum musivum* may be used; than which nothing can apply more closely to the smooth surface of the glass, as is found by long experience.

But now there comes before us a circumstance equally certain and extraordinary; for as soon as the separation commences at the cushion, there commences with it an *indraught* of the same fluid; which must be supplied through some channel, which forms a communication between the cushion and the body of the earth. A communication with the atmosphere is not sufficient: there must be a communication with some non-electric body: and that body must communicate with the earth itself, which on account of its magnitude can furnish a constant supply, without suffering any sensible alteration in itself; so the fluid comes freely from thence through the pores of any non-electric, in quantity sufficient for all our purposes, and at all times, as from an inexhaustible promptuary. In a word, it comes from the world to the machine, not from the machine to the world, as was at first imagined. To prevent the electric flux from being dissipated after it has passed the cushion, a skirt or flap of prepared silk is added to the cushion, which covers the glass more or less according to its size; and in this form an electric machine will do its work, but never so compleatly as when all is perfectly clean and dry, and *warm from the fire*. The fluid thus collected and in motion will make its way into all non-electrics near enough to receive it, and be equably diffused through their whole dimension at once. Into the air, when dry, it will not evaporate, but by degrees and slowly: for the pressure of the atmosphere is the antagonistic power which concentrates and confines electrical, as it does common fire: and this pressure will have its effect in keeping in the electric fire, though a bar of iron be red hot, nearly the same as if it were cold. Let a bar of iron be made red hot only in the middle; we shall find that the electric Fluid will pass from end to end without interruption. This does not prove that fire and the electric medium are two things, but only that they are two different modes of the same thing, as wind and sound are two modes of air, which give no interruption to one another. The effect of the atmospherical pressure is greatest when the air is dry: but if it be totally withdrawn, the electric matter which is communicated flies off, for the same reason, as an heated body grows cool sooner in vacuo: air being in all cases the antagonistic power to fire. This is the reason why the matter flies off so easily from a sharp point; the pressure of the air being little or nothing upon it: but the form in which it goes off is worth observing. It is that of a cone or brush; which cone is always attended with a blast of air, in a direction from the point outwards; which direction in the air must denote the same direction in the cause. For this reason, *a blowing point* is always supposed to *give*, while a receiving point is marked with a small star, or luminous ball upon the end of it.

The escape of the electric matter in vacuo is attended with this curious circumstance, that instead of diverging, as when the point blows in air, it goes right forward in a line. This it never would do, if the parts of the fluid were endued with any quality of repelling each other, to which the elasticity of a fluid is commonly ascribed: for if it were what we term elastic, it would shew itself to be so when it is most at liberty.

It is a great entertainment to observe, how powerfully the internal parts of glass are affected, when the electric spark is repeatedly applied to them. Let a thin receiver of glass of some length be well exhausted of its air; then let the spark be repeatedly directed to one point of its superficies; after which, if it be removed into the dark, it will be seen to flash of itself by intervals for a considerable time; as if the parts of the glass had been disturbed in their natural situation (as they certainly had) and required some time to recover of their vibrations: in doing which they sometimes fly to pieces. When these compound experiments of the higher class are repeated, they will not always be found to answer, by reason of some slight differences in the apparatus of different persons; but the ramifications of light, which play withinside an exhausted glass when its outside is electrified, are commonly known, and are extremely beautiful.

Great pains have been taken to measure the velocity with which this fluid passes through the internal substance of bodies: but that question could never be resolved; and it has been pronounced instantaneous. And there is a remarkable circumstance, in which Electricians were formerly well agreed; that its force is rather increased than diminished when it passes to a distance; which could not possibly happen if this matter were affected by a *vis inertiæ*, either in itself or in other bodies. It certainly flies upwards or downwards, to the right or to the left, with equal force and velocity. A matter of such force, acting according to no known laws of gravity, projection, or attraction, is a new phænomenon in the regions of natural philosophy, and must disturb people in some opinions wherein they have long rested: and on this consideration it is to be feared there are those among the learned to whom it hath not been a very welcome guest.

When I say that the electric fluid is subject to no attraction, I do not mean to deny the fact, that in Electricity bodies are by some means or other drawn towards one another: but I mean that the fluid is subject neither to attraction nor repulsion *in itself*. Repulsion has indeed been ascribed to it, as it also hath to the air; but I believe it to be neither in the one nor in the other, in the sense commonly intended; but that *apparent repulsion* is *occult extension.* If electric matter were actuated by any such power, it would discover itself most in vacuo, where we see nothing of it.

I am now coming to a part of our subject which has never been touched, so far as I can discover; and I have turned over some books with this view. It is an allowed law of nature, that from any space, which is filled with any medium, nothing will come out till something is ready at hand to take its place. This used to be called nature's *abhorrence of a vacuum.* When the electric medium flows from the conductor of a machine, some other matter must have access to it, without which the efflux can neither begin nor continue. It has been a question with me, in which of these two the motion begins; or whether it begins in both at once, as when the opposite sides of a wheel begin to move in contrary directions at the same instant. From what appears, the first impulse is *toward* the machine, and I was induced to think so by the following experiment.

The jet of water, which springs from an artificial fountain, is observed to take three different forms. When left to itself, it ascends in a small column, till toward the top it breaks into sprigs or drops, which diverge a little and fall to the ground: this I call its first or *natural* form. When it is electrified, the sprigs begin to diverge near the bottom of the column; and may be made to spread themselves over the room, much after the form of a weeping willow: and the whole field of natural philosophy scarcely affords a more beautiful spectacle: I call it the electrical *Tree.* This is the second form. But there is yet a third different from both. For if the wheel of the machine be stirred very gently, so as to render the power perceptible in its beginning, it is then seen that the first impression is *from without*: for the jet instead of diverging at the top after its own natural way, shrinks back upon itself, and resembles the head of a club. This is an easy and sure experiment, which never fails, if the wheel be gently moved at first: and it speaks to us a language of great importance. For from hence we learn, that the power of Electricity is inwards before it is outwards: and farther, that as the two artificial forms are two *states of Electricity;* so is the common or intermediate form a state of Electricity; the natural state; in the producing of which we have no share: and if so, the natural state of the world is a state of Electricity; that is, the electric element is silently and constantly regulating the motions of nature, whether we observe it or not.

Being desirous of seeing this order of the powers in Electricity farther confirmed, I made the two following experiments. I fixed a pointed wire to the conductor, and held another point directed toward the conductor in my hand. It was always observed, that the point in my hand shewed its light first. It is scarcely necessary to add, that this must be done in the dark. When bits of light paper were placed, one on the conductor, and the other on a stand, two or three inches below the conductor, and the wheel was *gently* moved as in the experiment of the fountain, the paper on the stand always flew toward the conductor before the other flew from it. But after all, what need is there of this trouble? for does not every spectator see that light bodies are always attracted before they are repelled? whence it is evident that attraction is first in order.

While I have been thus inquiring which is first in order, the afflux or the efflux; hypothesis denies that there is any afflux at all; affirming that it is all efflux. The Abbe *Nollet* persisted in the doctrine of an afflux; for which *Priestley* paid very little regard to his authority. Dr. *Watson* saw the reasonableness of it very early, and took great pains to prove it. He suspended upon silk lines both the machine and the man whose hand excited the globe; which cut off all communication with the earth: and in this situation the man and the machine produced little or nothing. But when a person standing on the ground touched the conductor with his hand, the man at the globe yielded sparks. This proves that the machine is without a supply, till it is furnished by the person who stands upon the ground. What he furnishes comes in a direction toward the conductor; and this is what we mean by an afflux. How it came to pass (if it really did come to pass) that Dr. *Watson* when he had demonstrated this principle, did not keep fast hold of it, is more than I can explain: but, according to Dr. *Priestley's* account of things, he gave it up. Men are struck with facts at their first appearance, and they speak a plain language about them: but when hypothesis comes in, and fashion gathers strength, they change their opinions. To me this experiment either proves an afflux, or it proves that there is little use in recurring to experiments for information; and that experimental philosophy may be as uncertain as any other. The experiment of Dr. *Watson* is really nothing but the common experiment reversed. In the ordinary way, a person stands upon the ground; he rubs the glass; and sparks are taken from the conductor. In Dr. *Watson's* way, the man suspended on silk lines has the place of the conductor; and so every common experiment proves the same with the operose experiment of Dr. *Watson.*

Before I can attempt to explain the double force, or shock of Electricity, I must lay down some preliminary observations. The matter of Electricity is differently received by bodies of different constitutions, which we distinguish into electrics and non-electrics. In the former class are amber, glass, resin, pitch &c. and these are held to be impenetrable by the electric medium. The non-electrics are metals, water, linen &c. which give it a free passage; and are therefore denominated conducting bodies, or conductors. In its degree this distinction is true; but it is subject to *conditions:* for electrics become conductors, when we change their condition in respect of heat and cold. Glass when red hot gives a free passage to electric fire, as other bodies do; its constitution being then relaxed, and its pores more open; which is the best reason we can give. I say then, that glass, which can become totally penetrable, is never totally impenetrable; but more or less so, according to the state of the fluid inclosed within it. The electric Fluid can resist itself, though it is not resisted by other bodies: therefore what happens to it is not to be imputed to the bodies, but to the condition of the medium within them. I premise this, because it is necessary to a solution of the Leyden experiment, or what is called the shock. This shock happens, when an equilibrium, which had been interrupted, is suddenly restored. That an equilibrium is *restored*, nobody will wonder, because it is the effort of nature to preserve it. But how is it *interrupted?* Here lies the whole difficulty. I find then that glass, commonly supposed to be totally impenetrable, can be so only to a certain degree. That the fluid passes it with difficulty is certain; but when it has done this, the two sides of the glass are in two different conditions: the medium is divided into its two constituent parts; which parts are by nature always mixed together in due (and perhaps in equal) proportion. These two will not part without difficulty, and under particular circumstances; and as soon as the way is open, they will unite again with violence; which violence is more or less, according to the difference which had taken place between them.

Two different powers in Electricity are so manifest, that as to the fact itself we shall meet with no opposition; but in defining the fact, people differ very much. Some call these powers more and less; positive and negative; vitreous and resinous; others are contented with calling them powers, and say they are contrary. Two *things* they certainly are not; for in kind both are the same; but they differ after a particular *manner*, of which our senses have not hitherto furnished us with an idea; and when we talk without ideas, words are but of little use. If we call the one A, and the other B, we shall explain as much as we know, without the danger of speaking falsely.

In a case nearly allied to this, I and all mankind are forced to be content with a knowledge of the *fact*; because a *reason* cannot be given. When the white rays of light are parted by a prism of glass, one extreme is *red*, the other *blue:* they are differently refrangible; they affect the eye with different powers; and when the glass is no longer interposed, they unite immediately, and become as they were before. Nature is here put out of its course by the *interposition of glass;* and discloses to us a wonderful and beautiful spectacle. But if any one should require me to define what and why these colours are, and how they came to unite so immediately after they had been separated, I am totally at a loss, and must rest myself upon the fact. The case is the same in Electricity. The interposition of glass separates two powers, which we did not perceive before: but what they are in themselves, and in what respect they differ, who can tell? One of them may be derived upwards, from the body of the earth, and be in its quality *terrestrial Electricity;* the other may be derived from the sky, and be *celestial,* *aërial* or *solar Electricity:* but from whencesoever they may be derived, they part with difficulty, and unite with violence. This is sufficient for our purpose.

Let us say then, that if across a current of electric æther, as it is conveyed from a machine, a square of thin glass be interposed, this æther is not absolutely stopt, but so checked, as to be divided into its two powers; which are now resident on the different sides of the glass, and kept there by the pressure of the air: for if a vacuum be adjoining to the upper side, which I call A, the glass will not be charged. By the action of the machine on the glass, and the re-action of the glass on the machine, things are brought to this state. The experiment is commonly made with a bottle or jar of glass, coated on each side in such a manner that the sides cannot communicate: but whatever the form may be, the sense of the experiment is still the same. When a communication is made between the two sides, they *neutralize* each other, like *acid* and *alkali*, which meet with a similar commotion.

Frequent inquiries have been made, to determine how these two powers meet; that is, which goes to the other, when the communication is open. Call the power next to the machine, which is commonly the uppermost side of the glass, A, and the opposite B; reason will assure us, that if there be an accumulation, it must be at A, where the force is directly applied, rather than at B; and that the equilibrium is restored in a direction from A to B. Yet arguments are brought to prove that they restore each other by a reciprocal motion; and that B does as truly move, in the article of the shock, towards A, as A towards B. But instead of pursuing this, I shall mention to you a curious fact; which shews, that the two powers may change places, and the Leyden experiment may begin with B as well as with A: and if so, that neither of the powers can be *negative*, but that they are both *active*, and therefore both *positive*. Charge a Leyden bottle fully, with a chain hanging from the outer coating to the floor. When the bottle is charged as far as it will admit, unhook the chain from its bottom. The outside is then in the condition which is called *minus:* but from this minus, another bottle may be charged as the first was, and both in appearance will yield a like explosion. This seems decisive against *plus* and *minus*.

The permeability of glass may be inferred, by comparing the different modes of performing the Leyden experiment. The same effect which is produced by the interposition of a plate of glass, may also be produced by the interposition of a plate of dry air, which is another electric body: but whether the experiment be made with glass or with air, the cases must be similar, and the principle one and the same. If so, the permeability of air will infer the permeability of glass *.

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* The Rev. Mr. *Lyon*, of Dover, asserted the permeability of glass, and produced an experiment to shew it. He discharged a Leyden phial and completed the circuit through a plate of crown glass without breaking it. This the reader may see in the account he gave of his experiments. The authors of a periodical publication, the partizans of Drs. *Franklin* and *Priestley*, contradicted and misrepresented him in a very illiberal manner; and it is not in my power to settle their differences.

To compare and rectify all that has been advanced for and against the two powers in Electricity, would be an endless labour: we should be bewildered and lost amidst a contrariety of words, facts, and opinions. Two powers, call them what you will (any thing but negative and positive) are separated out of the same medium; and do after their separation unite with violence: and when this is known, we have reason to be assured, that the same powers which do this, must do many other strange and important things in the natural world. I have little inclination to multiply terms after the number which this science has already brought into use: but it might perhaps be of some advantage, if we were to call the stream first excited, by the name of *single* Electricity; and the shock from the two powers *double* Electricity. Before I conclude this letter, I shall offer a few words on the *effects* of each.

By single Electricity, the electric motion of nature is increased; as the heat, natural to the atmosphere, is increased when we light a fire. When a person is electrified, the course of his blood is accelerated: when a plant is electrified, its vegetation is promoted: when a vessel of water is electrified, its evaporation is increased; like as when it is heated over a fire, but in a much smaller degree: consequently the perspiration of an animal body is promoted, for that is one species of evaporation. A leaf of gold may be suspended between two plates of metal; and in that situation it must be between two forces equally balanced. Fragments of leaf gold, or other light bodies, may be even suspended in the air near to a conductor, and are sometimes observed to be whirled swiftly around it. This sight astonished *Stephen Grey*. He saw a disposition in bodies to revolve about an electric centre, and was transported with it; but could not reduce it to any thing regular. A downy feather electrified is extended in every fibre, as if it were a plant growing out of the earth in full vigour: but when the current of the fluid is withdrawn, it falls flaccid; as a plant does, after it has been separated some time from the earth. The silent operation of this universal power in nature is permanent; it is at work day and night; though it must be subject to a fluctuation. It is not like the force of the wind, which comes and goes; it rises with a perpetual supply from the body of the earth. No man can doubt, but that the same things which we do by art and violence, are constantly doing in the course of nature. What we do is like raising a sweat: what nature does is like insensible perspiration. Every moment must this power be working upwards from the earth; and having a passage through all vegetables, it gives them their erect position. And let me add (for such is the order of nature) that a current in one direction implies another current in the opposite direction; as the efflux in electricity is always attended with an afflux; and if I could not see it, I should reason myself into it by analogy a priori. Even the skin of the human body is liable to absorption as well as to perspiration; and strange things are known to happen to us on this principle. In like manner, if the earth perspires, it must absorb; if there be a force acting upwards, there must be another acting downwards from the heavens; and this will account for the descent of roots into the earth. The two powers will be more particularly at work near to the surface of the earth; where their counteraction occasions that stubborn hardness and firmness, which is found at the bottom of the trunks of trees, and the stems of more tender vegetables.

By simple Electricity we are now possessed of a method of exhibiting that illustration of the celestial motions, to which *Stephen Grey* so much aspired without success. We can communicate Electricity in such a form, as to produce in a spherical body a *revolutionary* and a *rotatory* motion. The experiment was first made by Mr. *Rackstrow*, an operator in Fleet-Street, and excited much attention. The manner in which it is now best performed, is such as I shall describe to you.

A ball about the eighth of an inch in diameter, which for the sake of its levity is made of cork, is cut with a knife as nearly spherical as the eye can judge, and covered completely with a coat of sealing-wax or sulphur. This is turned to an exact sphere and polished. A circular plate of metal very smooth at the edge is placed on a cake of wax or sulphur about half an inch in thickness, and laid on the transferring plate of an air-pump; so that the interval, between the plate of metal and the rim of the transferring plate, may just allow room for the ball to move freely around. To the upper plate a chain depends from the conductor of a machine; and as soon as the plate is electrified, the ball begins to revolve; turning at the same time upon its axis, and continuing its revolutions so long as the machine acts upon it. The reason of the phænomenon is this. The ball is between two powers: it is both attracted and repelled: but being an electric body, it can receive the impression only on one point of its surface at once; which point being continually turned away, and a fresh point being presented, the result of this is a revolution and rotation. Mr. *Grey* pleased himself with having discovered, as he thought, a disposition in light bodies to move from east to west, like the planets: but that was a deception. This ball revolves either way, as it happens to take the first impulse. If stopt in its course, it will begin again as often as the operator pleases. I do not reason upon this fact at present, reserving that for another place. But I will mention, while it occurs to me, that in the presence of two learned gentlemen I made the globe revolve (as it did very freely) under a large receiver of an air-pump: from which the air being exhausted to twenty-seven inches, the globe would not stir.

The effects of double Electricity, or what is commonly called the shock, are now so universally known, that there is little to be said which has not been said before. The convulsion it occasions in the muscles of the body, through which it passes, can be understood only by those who have felt it; and even they are under a difficulty how to find words to describe it. I suppose the fiercest beast upon earth might be terrified by it; and I have often wished to see it tried upon a lion or a tyger, or a furious unmanageable horse; it being very probable, that the wildest horse might be broken by the proper use of it.* I had myself a dog, a beast of strength and spirit, but of great good humour, who having felt it a few times, would never after endure the sight of a common vial; but would fly at the person who held it towards him, though it were his own master; so lasting is the remembrance of the sensation. Now as the artificial or violent motion of the muscles is the natural motion of them increased; the cause of the violent is the same with the cause of the voluntary. Nothing seems wanting for this purpose but subtilty and power; and it has them both. Involuntary cramps and convulsions must surely be occasioned by the irregular and involuntary agitations of the same cause that produces the ordinary and voluntary motions. While its powers are balanced, we feel right, and are as if we felt nothing: but if the balance be interrupted on one side, we are sensible of a powerful agent, which gives us violent pain. In the distemper called the *tetanus* and *opistotonus*, the contractions or extensions are violent and intolerable.

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* The shock was given to a horse at Vienna, who was unmanageable, and absolutely tamed him, by Dr. Ingenhouse.

The two great meteorological examples of double Electricity which nature presents to us, are those of thunder, and of the water spout. That thunder and the electric explosion are but different degrees of the same effect, is now well proved, and universally allowed: but it is difficult to shew how the analogy holds between that great phænomenon of nature and our experiments. I would argue thus upon the case: that as the Leyden experiment may be made, not with glass only, but with air interposed between two non-electric surfaces; I would consider the clouds above, and the earth beneath, as these two non-electrics, and the air between them as a plate or medium of separation. So long as the air is humid enough, the intercourse is kept up between the upper and lower region; and the changes which happen in meteorological Electricity are brought to pass without commotion. But when the air becomes very dry (chiefly from heat) the communication is intercepted and the two powers are separated. As the clouds assemble and increase, the charge above increases till it can be sustained no longer: when what I called A in the Leyden experiment, being redundant above, while B is redundant below (or vice versâ) an eruption of fire happens to restore the equilibrium. This is rarely done at one explosion, for two reasons: first, because the plate of air when broken through recovers itself again, till another explosion makes another breach; and secondly, because the clouds, whence the lightning proceeds, move forwards in the sky, and pass over fresh parts of the earth's surface, which require a like saturation by a new discharge from above.

In the Leyden experiment, the discharge is effected two several ways: either by the circuit of the wire or chain &c. or by a short way, through a fracture of the glass itself; which sometimes happens when the charge is over great. In the sky, the effect is brought to pass according to both these methods. The explosion when violent, will break through the interposed dry air, as it breaks through our glass: but when the rain falls from the clouds to the earth, the same thing is done by the circuit: and perhaps this may account for the difference between the *bolt-lightning* and the *zig-zag*. What I have here said, cannot pretend to be more than a rough sketch from the imperfect idea I have formed in my mind of this great and complex operation of nature, to which we are so frequently witnesses. Times and circumstances produce varieties, and create new difficulties, which demand more accurate solutions than we are or ever shall be able to give. Whatever we may presume, but little is known with certainty to us in the whole subject of *meteorology;* from the comet that blazes in the sky, down to the luminous vapour that dances over the bog. I am nevertheless persuaded, that the compositions, decompositions and recompositions, which happen in atmospherical air, about which the learned have been so inquisitive of late, will be found to proceed chiefly from combinations, attachments, redundances and deficiencies of fire in its electric capacity, if our observation shall be able to follow them minutely enough.

The water-spout seems to be nearly allied to the thunder-cloud; and to admit of a similar solution. Here the two great non-electrics are a dense cloud above, and the water of the sea below: and the preparation is either from a preceding heat or dryness of the air; on which account they are seldom seen but in climates nearer than ours to the sun. From a thunder-cloud a flash of fire restores the equilibrium: but here, the communication is effected by means of the water of the sea, and the water of the cloud; which, meeting together, form a column, consisting of two twisted or spiral shafts; the one from above, the other from below; which whirl together in a furious manner, the one ascending the other descending, till both regions are reduced nearly to an equal temper; when the column breaks asunder, and sometimes with a flash of light, which plainly indicates what agents were at work on this occasion.

The force of *whirlwinds* is too great to be accounted for by that force of the air which arises merely from rarefaction and condensation. I would rather suppose the water-spout to be a wet whirlwind, and the whirlwind a dry water-spout. They both partake of the same whirling motion; they both pass forward in a line; the one over a tract of land, the other over a tract of sea. Lightning itself seems to partake occasionally of this spiral motion: it having been frequently observed, that trees rent by lightning have borne the marks of having been twisted and wrung asunder, as if two contrary powers had acted upon them at once.

And this is more agreeable to the workings of nature, than that a gyration should ensue from the motion of a single power. All *eddies* whatsoever are most naturally formed by the meeting of two contrary currents.

I trouble you no more at present with the effects of Electricity, natural or artificial: intending to go a step farther in another letter; in which it shall be inquired (and that not *factiously*, but as candidly and rationally as I can) how these things agree with some opinions which are commonly admitted; and how far systematical philosophy may be corrected by them. So long as Electricity gives us nothing but a *new sight*, we are children: if it gives us new truth, it may turn us into men. Popular error, if it stands in our way, will not suffer us to proceed unless we can remove it: my next letter will show you what I mean: till when believe me

Your most obedient &c.

January 12, 1797.

LETTER IV.

IT was observed in my last letter, that a force, such as we discover in Electricity, acting by no known laws of projection, gravity, or attraction, must affect some opinions commonly received in natural philosophy: therefore you must prepare to hear me with patience.

There was a time, when the two *qualities* of attraction and repulsion, considered as agents of nature, were thought nearly sufficient to govern the world: they were accordingly applied, as to all other things, so to solve the new and wonderful appearances in Electricity. A repulsion was supposed between the particles of the electric fluid, and an attraction between them and all other bodies. This was short and easy: but neither of these positions are true: for if the particles of the electric fluid repelled each other, they would do it most in vacuo, where they have most liberty to exert themselves. But this does not agree with fact; they diverge most in air, and go in parallel lines through a vacuum. There is another fact of great magnitude, which does not shew that they are attracted by other bodies: for if that were true, how could they flow so freely, as they are observed to do, from the vast body of the earth? If it attracted them, it would retain them; but from the earth they are drawn away more easily than from any other body. The electric fluid is therefore not directed in its motions by these qualities, but by certain laws of impulsion, whatever they may be. When *Stephen Grey* and Mr. *Wheler* first made their experiments, it was not to be wondered at, that they never reasoned right; for Electricity did not agree with any of the pre-conceived notions of philosophers. And this we may say without any offence to the fame of *Newton*. Time has brought forth many strange things; but the great work of *Newton* will always stand the first in its kind, which the capacity of man ever did or ever will produce. Give him ground to stand upon, and he moves the world. With all the properties of the conic sections, and the most profound applications of them, he plays as freely as the whale plays with the waters of the ocean; sometimes near to the surface, and sometimes at the bottom of the deep; where none but the inhabitants of the same element can follow him. His genius had this great advantage, that gravity, call it what you will, must be admitted as an actual force in nature. It must also be admitted that the joint effects of compounded forces may be so demonstrated, that the conclusion cannot be denied. But here in Electricity, we have a power doing mighty things, of which power the laws are not yet settled, and perhaps never will or can be, so as to be measured and computed. Of this new power we may be permitted to say something in a new manner, without intending any offence to the fame of *Newton*. At the time when he surprized the world with his discoveries, the philosophy of *Des Cartes* was in possession: who went upon the hypothesis of a subtile matter in the universe, acting with a vortical motion; which vortical motion *Newton* demonstrated to be not agreeable to the laws of nature. *Hypothesis vorticum* is the philosophy he opposes. That he was an adversary to *subtile matter*, does not appear; but the contrary. In Mr. *Cotes's* preface indeed, all subtile matter is discarded from the creation with an high hand: but that is not Sir *Isaac Newton*; it is Mr. *Cotes;* who affirmed too hastily, that *no such thing could be proved to exist, either to the* sight *or to the* touch. How the fire and force of lightning came to be overlooked, as not existing, or not appertaining to natural philosophy, is a difficulty for which I shall not endeavour to account. Mr. *Cotes* was admirable at hydrostatics, and many other things; but *pyrostatics*, which ought to stand first in order of nature, are a study for which the learned were not so well prepared then as they are now. The posture of things is very much altered: we have a subtile matter risen up, as evident to the sight in a private chamber, as the lightning itself is in the sky; as evident to the hearing, as the noise of thunder or artillery: and whether it be evident to the touch, let any person judge, who has felt the force of it. Here then we have a matter disclosing itself to the *sight*, the *hearing*, and the *touch*, by its appearance, its noise, and its force: that it is *subtile* matter, none of us can

deny;

deny; for it passes through iron and brass; and if it is resisted in glass, it is resisted by *itself;* for the materials of glass in their raw state, discover no such disposition to resist it: and if they resist it in the form of glass, it must be because the glass brings with it from the fire the same sort of matter, seated and fixed in its substance, after a manner we cannot understand; but which gives such an arrangement to its parts, as is necessary to its transparency; and occasions those unexpected and obscure fractures to which glass is liable without any visible cause. That it is *matter*, is certain; because it is resisted; which could not happen if it were *nothing:* and its *subtilty* is equally certain, because in other cases it is not resisted, but moves as freely as if it had a power over all other matter.

Contrary to the positive assertion of Mr. *Cotes* then, there is a subtile matter existing; and existing every where; in all places and in all bodies; and by what arguments soever it might once be discarded, it is now come again, and will remain with us to the end of the world: and he who thinks it may be left out, and that philosophy may be complete without it, is rather to be pitied than argued with.

It was observed by Electricians many years ago, and they were generally persuaded of the fact, that the force of an electrical shock is greater, when the passage of it is long, than when it is short: and if so, it must rather acquire strength than lose it in passing to a distance; even through hard and solid matter. If this fact be true, it is not within the laws of nature, as hitherto established,

established. Philosophers have taught us, on what terms a force once communicated may continue the same, and how it may change from more to less; but never how it may change from less to more, without the accession of some new force. When a planet is accelerated, as in its approach to its perihelion, this is never supposed to happen, but because it acquires a new force from the power of gravity. But here no such accession is to be discovered: on the contrary, a solid body is interposed, which ought to interrupt the force, and lessen it. The laws of nature, as commonly applied, do not hold in this instance: in the case of artificial or violent forces, they may take effect: but under these the forces of nature are not comprehended. Art goes from more to less; nature from less to more. This is most notorious in the progress and increase of the force of fire, from a single spark to the overthrowing of a city: the consideration of which fact so astonished that ingenious man *Cadwallader Colden*, Esq. of New York; that he denied the *vis inertiæ* to be an universal property of matter.

It was thought, and it has of late been re-asserted, because it is supposed to have received some new evidence, that gravity is common to *all* matter; not as an *effect*, but as a *power impressed* by the Creator; or, as others have worded it, depending only on the *will of the Creator;* but here we have a sort of matter, on which gravity is not impressed, because it is indifferent to every direction; which matter under the power of gravity cannot be. It will appear some time or other, that the cause of gravity must itself be without gravity. It will farther appear, that no solid matter whatsoever, either moveth itself or is moved by *impressed virtues*; but that all matter which is solid, is moved by other matter which is fluid; and that this is an universal law of nature, to which there is no exception. If gravity were an effect without an impelling cause, it would stand single in the world, and contradict every thing else. For all motion in matter, so far as it is understood by us, is found to proceed from the motion of other matter; till we come to the first cause; and it is neither philosophical nor rational to suppose that the first cause is the immediate cause of gravity, till we are able to shew that no other cause is intermediate. Does it not appear, that gravity is a material force, from its being subject to a mechanical law; I mean, that law, by which it is *added to itself by equal portions in equal times?* That which is immaterial is not subject to be measured by time; therefore gravity is from the force of something, which *acts in time*, and is *measured by time*; that is, from some *matter*: and the world can shew us none so adequate to the purpose, as that which is the subject of our present enquiry.

All I have here been saying agrees better with the doctrine of *Newton*, than with that of his followers. The ingenious *Dr. Hugh Hamilton* of Dublin (whose cruel death has of late been so justly lamented) confessed in his Lectures, that " it still remains to be de-
" termined, whether these forces of gravity, and co-

"hesion, arise immediately from the will of the Supreme "Being; or are the effects of some secondary or mechanical cause, which He is pleased to employ in carrying "on the operations of nature. Sir *Isaac*, from some "phænomena, was induced to suspect, that the immediate cause of gravity was mechanical."* Since this opinion of *Dr. Hamilton* was published, it has been asserted, in the name of the Royal Society, that the doctrine they now hold, is that of an *impressed quality common to all matter;*† which is to determine, contrary to *Newton* himself, and *Dr. Hamilton* after him, that the cause of gravity is not mechanical, but an unmechanical quality of all matter. I hope I do not misrepresent the worthy President: I do sincerely take this to have been his meaning: and certainly every opinion of the Royal Society deserves respect, because it is theirs. They are a learned body, to whom people who are less knowing ought to look up for true doctrine in philosophy: but I cannot, against the doubts of *Newton* himself, acquiesce in their doctrine of *impressed qualities;* which, supposing there are such things, enable *inert* matter to *act* upon other matter *without touching!* I am glad this doctrine was never put into the articles of our faith; for I could not have received it: I can as soon believe, that every brass cannon brings its own powder with it from the foundery. But though I say thus much, I am nevertheless persuaded, that many who did believe the doctrine of *im-*

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* Lectures III. p. 86.

† See the Discourse of the President, November 30, 1775, p. 4.

pressed qualities, and argue for it, were persons of good meaning, and great learning: particularly the famous *Dr. Bentley*, who consulted *Newton* upon it, and was told that the notion was *an absurdity.** No small nonsense has been engrafted upon *Newton*; and I may add, no small wickedness: for even Atheism has sought a shelter for itself under his name, and would willingly be thought to partake of his wisdom. But his principles, as he delivered them to the world himself, are *mathematical* principles only. Even gravity is used by him as a mathematical force; into the *physical* or metaphysical consideration of which he never professedly entered. Others did it for him; and then put his authority to their own opinions: so that if I am making any opposition, it is not to him, but to them.

Ever since I practised Electricity, I have argued thus with myself: that attraction, as observed in Electricity, is no *impressed force*; because I try it on the air pump, and I find, that when I take away the air, that impression is gone, though it is then most at liberty to act and shew itself. I argue again, that attraction cannot belong to the solid parts of matter, because I take the light shavings of amber, the most attractive of all electrics; and I find that the same particles which were *attractive* in the mass, are now *attracted* in the parts, like those of any other body. I therefore conclude, that as the same substance cannot be both active and passive in its constitution, the cause of its attraction must be something not inherent in its parts, but adventitious or external to its own matter. Having got thus far, I make a transition from the force of Electricity to other forces; and I still conclude that as this attraction is not in the solid parts, but in something adventitious; the same will be the case with other attractions; and all upon this principle, that nature is uniform in its operations and laws; I therefore go on to conclude the same of cohesion, chrystallization, the action of menstruums, chemical elections &c. &c. How subtile the cases may be I care not, nor how disguised by words: the quality called attraction always was a phantom from the beginning, and I believe no more of it, than I do of the stories about ghosts.

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* See his Letter to *Dr. Bentley*, in the 4th vol. of *Bishop Horsley's* edition of *Newton's* Works.

I say farther, that if I can prove attraction to be from an external cause in any single instance, I may *think* the same of it in every other instance, whether I can prove it or not: and I shall think rationally, because I think consistently. On the other hand, if any person advance any one sort of attraction, with an exterior cause, he must extend his principles to every other case in nature to make nature consistent. But in this he will never succeed; and he may thence infer, that his principle was not right at the beginning. If any learned gentleman can suggest to me a better train of reasoning, than this into which I have fallen; I will hear him with patience, and go over to his side of the question. I have no attachment to any thing, considered as mine: all the philosophic fame in the world is no object with me; let *Dr. Priestley* have it all, who has been courting it for so many years. But truth is a great object, and the more so, because truth in one subject breeds truth in another, and *vice versâ.*

The argument I am now pursuing, may be extended to *Kepler's Law*, which is known to obtain in the heavens, and confirms all I have said. For as it was observed above, a mechanical law must be the law of a mechanical force: if it measures matter, it must have matter to measure; for spirit is not the subject of geometry. Any mechanical law will certainly suit better with the force of a *fluid*, which is mechanical, than with the force of a *quality* which is unmechanical. What *Kepler* himself might have produced out of his own law, if instead of his old speculations he had been guided by the new discoveries of modern times, it is above me to conjecture. Whoever reads his Epitome of Astronomy, will find that his head was filled with the mystical idea of attraction from *Gilbert's* Magnetic Philosophy; and his mind much given to fanciful speculations on geometrical solids. But so it came to pass, that out of all his fancies that wonderful discovery emerged, which is the foundation of modern astronomy.

I observed to you at the beginning of my first letter, that the science of Electricity rose up in the world at a remarkable time; and so you will think, if you consider it. *Newton* had found, that the heavens contain such matter, as cannot be discovered to make any resistance to the celestial motions: which is reasonable and true; for the cause of motion, whatever it may be, will never be found to resist the motion which it causes. But his followers went a step farther, and emptied the heavens of all their matter. Things were in this state, when the new powers of Electricity broke in upon us. You may think they came at the moment when they were wanted; and so I think: but if we were to judge from the little use which has been made of them, they came at a time when they were not wanted; when those who were most learned in philosophy did not know what to do with them; as supposing that the whole business might be done without them, and that they could only stand in the way and be troublesome: for new governors bring new laws; and new discoveries, so different from the old, will bring new thoughts: I wish *Newton* had seen them: he would have pursued them, and brought something great out of them. But without him, who dares to begin? and if he does begin, who will thank him for his labours? for labours of which the world feels no want? Thus it hath come to pass, that Electricity has given us no new principles: in that respect we seem to have been at a stand for many years: if we have been progressive, it has been chiefly in the application of it to the cure of bodily disorders, where it has been of great use. In this capacity I shall therefore speak of it in my next letter.

I am, Sir, &c.

January 15, 1797.

LETTER V.

AMONG the remedies of diseases, there is a class which may be called philosophical: by which we mean, such remedies as are independent of the apothecaries drugs, and the surgeons instruments, and consist chiefly in the proper use of the elements. These being nearly related to the powers of life, may reasonably be expected to do much good or much harm. The qualities most obvious in the elements are those of heat, cold, moisture, dryness; nearly related to which are diet, exercise and clothing. Heat and cold are powerfully applied in the form of the hot and cold bath; to which the vapour-bath has of late years been added with great effect: but one of these must not be used when another is more proper. The natives of America, when the country was first discovered, had a method of curing fevers by sweating, first in a hot room, and then plunging into cold water: the intention of which was, first to let the enemy out, and then to shut the door upon him. But when these poor people applied their old method to the small pox, they killed instead of curing themselves. Dryness of the air is generally wholesome; whence the inhabitants of mountainous countries are more hardy than those of vallies and marshes. Yet moisture is in many cases serviceable; but *cold* moisture draws off the animal heat, and diminishes the vital powers. Near to the sea if there is a clean shore, the air is more pure than within the land: and the mere air of the sea, from some quality not perfectly understood, has a specific power in removing severe coughs which will not yield to medicine; as I found by experience twice in the course of my life. In common meats and drinks there is nothing of medicine: but the proper use of them is of the first importance; for which cause the dietetic part of physic is much studied by physicians and well understood. Often might sick persons be relieved by the observance of some plain regimen without the use of a single medicine: and the remedy has two advantages; it is cheap and it is lasting. But how and when shall we give wisdom to the idle and the intemperate?

In the subject of our clothing we have now some knowledge which is entirely new: for the garments we wear are distinguishable into electric and non-electric; the effects of which upon the body are essentially different; for the former retain its natural heat, and the latter draw it off. To land-animals in general the Creator in his wisdom and bounty hath given a sort of covering, which keeps up and keeps in the heat of the body; and common sense teaches us to borrow it from the animals to which it is given. Hair, wool, feathers, silk, are among the substances which we call electric. How proud and vain are men and women when they are clothed with silk! but the first use of silk is to preserve warmth to a poor worm in its intermediate state. Linen on the contrary is cold, because it is taken from a vegetable, whose nature it is to conduct and carry off animal heat. Electricity has taught us to reason well about these things, and consequently to act with more safety and propriety. Many chronical disorders have been cured, or very much relieved, by the wearing of flannel next the skin. The fact is commonly known; but the reason is now better understood. We know not of a single annimal but man, that wears a non-electric next to the body. The first clothing man made for himself was taken from a vegetable: the first clothing the Creator made for him was of skins.* It is very observable that hair and wool, and feathers and silk do not easily take fire: they have it already in their constitution: but linen of all kinds receives it readily, having less of its own. It therefore makes good tinder, which can never be made of silk, hair, or feathers: touchwood, which is natural tinder, is also from a non-electric. In short, the new principles of Electricity have taught us to account for these differences, and the subject of human clothing is become at once curious and useful. The sensations also with which various animals are affected on changes of the weather, are now better explained than formerly, since we have known more of the changes of electric fire in the atmosphere. For the barometer alone, as indicating only the different weight and superficial pressure of the air, cannot account so well for that inactivity in the muscles, and those pains in the joints, which different states of the atmosphere produce in us: but minute changes in that fluid which acts upon the internal parts, or whole dimension of bodies, and has power to penetrate the frame and shake the bones, may be adequate to all that happens in this way.

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* See Gen. iii, 7, 21.

On all the foregoing considerations, we have reason to wish, that Electricity may never cease to be administered as a philosophical remedy, under some form or other. Physicians have said much on what they call the *non-naturals*; by which they mean such things as are exterior, and not of a medicinal kind. They have reckoned them six in number: this new power may now be added to them as a seventh.

There are five different modes of applying it. The first is a communication of it to the whole frame at once; which is what we understand when we say a person is *electrified.* The second is under the form of a *spark;* which may be stronger or weaker, according to the power of the apparatus or the intention of the operator. The third is the friction or flesh brush; of which method there is a good figure prefixed as a frontispiece to Mr. *Adams's Essay on Electricity*, designed by an eminent artist. The fourth is that of a topical brush from a pointed wire; or a point of wood, which renders the brush more soft and gentle. The last is the electric shock from the circuit of the Leyden bottle. The spark is the form I commonly prefer. If strong, it may be received at any point of the body, and discharged at any other point; in which case it certainly passes in a line from the one to the other.

The electric friction, or flesh brush, is an excellent form for rheumatic pains and paralytic affections; and it occasions a thrilling sensation, by which the spirits are remarkably raised as by a cordial. But in cases where the *shock* is proper, it is the sheet-anchor. It completely restored the use of the limbs the first time I had an opportunity of trying it on an hemiplegia: but the party was young, and of a strong frame, and the disorder arose from an accidental cold. Agues, after resisting the bark, have frequently been cured by it. Medicines are remarkably forwarded in their operation by the use of Electricity. A blister may be made to run which did not run before; and a cathartic, if slow may be made quick; sometimes very quick; which it may be useful to know in case of a stoppage. It is the only remedy for gutta serena, and very often succeeds. The fluid is generally used for gutta serena. I would observe upon the whole, that if a complaint is recent and the patient young, great things may be done: if the complaint is recent and the patient not young, something may be done. But if the complaint is of long standing and the patient not young, little can be done: yet even then there are cases, when an application of this remedy may palliate, and therefore be worth trying. It is now so far adopted by medical gentlemen, that an electric machine is reckoned a necessary part of the apparatus in hospitals; and many surgeons are furnished with one in the country; the ordinary use of which is in paralytic cases. It has been hinted to me however that the cobwebs are too seldom brushed off from hospital machines, and that the general answer of the faculty has been, they are too old to go to school again. It may certainly be extended to many other disorders with advantage: and the practice is in the hands of ingenious men, who make proper observations and keep journals of their proceedings in this part of philosophy. Many extraordinary cures have been performed by Electricity, and several cases have been read and published by the Royal Society; but how it happens that physicians know so little of this wonderful power, I am at a loss to account. Every year presents some new empiricism to them, which rages for its time and is buried in oblivion. Magnetism has had its advocates, hemlock, inspiration of medicated airs, and now the vitric acid, and the tractors; but the cures by Electricity stand uncontested, and the cases published (as a sequel to *George Adams's* Treatise) on medical Electricity are so strong, that no doubt can arise.

But unless a man has a mechanical turn, and is perfectly master of the instrument, he will so quickly put it out of order, that his experiments will stop. If a man would perform on the violin, he must know how to keep it in tune; and although many symptoms of a disorder may be relieved by the accidental application of Electricity, yet in the hands of a person skilled in the anatomy of the body, and the cause and seat of diseases, much more may be expected.

The modes of applying it may be so varied, that to an observer it would appear more like magic than science; yet all the modes are to be reduced under three heads. The stream which passes from a point, the spark which flies from a ball, and the shock of the Leyden phial. It may be extracted from the body in the same manner as it is directed towards it, by insulating the patient; or two sensations may be produced at the same moment, for the stream may be directed in at the eye from a glass-handled director with a point, and sparks may be drawn from any other part by applying a metallic ball.

I would not infer that in so liberal a profession as medicine, the desire is not to cure, yet when I hear the far greater part of a faculty speak against so powerful an application, without having any knowledge at all of it; and when the most skilful must acknowledge they have seen good arise from it, where it was least expected, I am led to suspect there is a cause to suppress it. It was many years before James's Powder was prescribed by the College, and even now a spurious substitute is introduced in lieu of it at the Apothecaries Hall, under the title of *Pulvis Antimonialis*. Electricity however is more likely to become a branch of surgery, because it is a manual operation; and surgery is making hasty strides towards improvement.

I say no more on the application of Electricity to the *Microcosm;* that is, to the system of the human frame. If we can apply it with any success to the *Macrocosm*, or frame of the world, we shall make a new step in philosophy: and this is what I shall attempt in my next letter.

Dear Sir, ever yours &c.

Jan. 17, 1797.

LETTER VI.

SIR,

WHEN we bring Electricity into a chamber, we know what we are about to do with it: but when we bring it into the *world*, who can say what it does, or what it cannot do? Before we can proceed upon this great question, it is to be remembered, that the principles of every science lie within that science itself; as the elements of every language are to be found in its own alphabet. One language gives help toward the knowledge of another: so are all the sciences related in like manner: but we are not to apply to one science for the principles of another. When philosophers amuse themselves with the balancing of weights, or the striking of balls, they are very ingenious men: but all this is the work of art; from which little can be gathered concerning the ways of Nature. If nature is to be explained, we must apply to nature itself; the principles of which have of late been so much farther opened to us by the discoveries in Electricity, that I shall take them chiefly from thence, and apply them in such a manner as I think you will easily comprehend.

The farther we inquire into the ways of Nature, the more clearly we shall see, that one grand principle is every where at work; which is that of contrary motion in two contrary powers. You must have seen something of this already from the foregoing letters; for it is no where more conspicuous than in the experiments of Electricity: but the same principle meets us every where. Who would attempt to account for the eddies we observe in magnetism, without supposing two such powers? We can neither see them, nor can we feel them, for we are not made of iron. If we speak accurately, we must not say that these powers are in iron or the loadstone; but that the powers themselves are in nature, and the *effects* of them in iron and the loadstone. It is easy to prove this: for let a simple bar of iron be any where placed in a vertical position: two powers are immediately found to act upon it, which cannot belong to itself. The top of the bar draws the north end of the needle, and the bottom draws the south end. To prove that these powers are not in the iron but adventitious to it, invert the bar; and the same end which in its former position drew the north end of the needle, will now draw the south end. What happens therefore is not from the iron itself, which is a passive body, but from some occult circulation in nature acting upon it; which is constant and regular in nature, but variable in the iron. The like effects will follow, if the two ends of the bar which before were vertical, are alternately placed north and south in the direction of the magnetic meridian. These wonderful things are brought to pass by two powers, which, though contrary in *effect*, are one in *kind*.

In the body of man, it is now universally known, that life is kept up by a contrary motion: and the ingenious *Dr. Woodward* took great pains to shew, that the seat of life is where that motion is; I mean in the *blood:* in which doctrine he is followed by the late *Mr. John Hunter.* And if from the body of man we make a transition to the body of the earth, we observe a like reciprocation in its winds and waters; in the breezes of the land and the sea; in tides and currents; in the cold of the poles and the heat of the equator. All things are going out, and all things are coming in; and the returns being equal though contrary, nothing is stopped, nothing is lost or wasted. Whatever others may find, it is in this certain and wonderful analogy that I have found the philosophy, which has always been to me the most satisfactory.* Let us only continue it to the Heavens, where it must prevail if Nature is consistent, and we shall have all we want; with the application of which, we may proceed as far as we can wish, or at least as far as we ought to wish, under the present imperfect state of human knowledge.

What strange effects two contrary powers will produce, we have already seen, from the example of the little revolving electrical globe. We see *that* situated between one of them, which brings it forward, and another, which drives it off; and their joint action upon it carries it round. With which soever of these you may think it proper to begin, the solution comes to the same: for while the repelling cause acts on one side, to turn away the point electrified, the attracting cause brings a fresh point forward; and thus the globe exhibits a rotation round its own axis, and a revolution in an orbit. The fact is undeniable, and the causes are undisputed.

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* This principle of contrary motion, as produced by the interchanges of heat and cold, has lately been opened and applied with great truth and ingenuity by *Count Romford* in his 7th Essay. Heat and cold are two of Nature's hands: the contrary powers of Electricity are two more; and there be many others constantly at work.

If, for the sake of illustration, it be lawful to whip a painted top, and gather from thence a good reason why the sun looks white; we may also be allowed to argue from this little sphere and its motion, to the great ball of the earth. In our present state of existence we are under the necessity of learning great things in this childish manner from little ones: and we ought not to be ashamed of it, for we cannot otherwise conceive them. I have therefore often amused myself, and I do so to this day, with considering my electric apparatus as a system similar to that of the Heavens; where the sun is the grand electric globe, exciting all things to an active state; while the earth and its atmosphere are conductors, distributing and applying to all bodies contained within them the force and life they derive from the centre. *Kepler* formerly considered the sun as the great *magnet* of the world, with an attractive side and a repelling side; and that by the influence of *both* he carried things forward; but we are now upon better ground than he was. We have realities before us, and have no need to call in occult qualities to our aid. For if the sun be the beginning and end of a circulating matter in the Heavens, then will every orb, however it may be placed, be situated between two powers; in which situation it can no more continue at rest, than the little sphere between the two powers of Electricity. One of its hemispheres will be toward the sun, the other will be away from it: consequently the one will be in light, the other in darkness; the one will be heated, the other will be cold: they will therefore be in two different conditions. This nature never permits, without an effort to restore an equilibrium, which equilibrium, if destroyed as fast as it is restored, can never be restored at all; and the constant effort of Nature to effect it, produces a perpetual motion. If the two powers are equally balanced, the orb between them will always move at the same distance, and the orbit will be a circle: if they vary, or prevail over each other alternately, the orbit will be elliptical, and the sun will be in one of the foci.

You will say perhaps, that this solution may be admitted in the case of a primary planet; but what are we to do with the secondaries? For we refer the primary orbs to a source of light; but the secondaries to an opaque body; and must not these cases essentially differ? So it was thought, and very rationally, at the beginning of this century: but Electricity hath now taught us, that the effects are the same whether the central body be opaque or lucid. The little sphere will revolve round an opaque body, placed at any distance from the electric fountain. In the motion of a secondary orb, there is now no more difficulty than in that of a primary: and there is the same reason why the law of *Kepler* should take place on the secondary with respect to the primary, as on the primary with respect to the sun. We cannot indeed assign any reason, why the progress of a planet should be from West to East, rather than from East to West: but we may presume to say, why the motion, when it has once commenced in that direction, will persevere in the same; from the causes which are known to act upon it. What these causes are, let us now consider.

The earth, at its western, or evening edge, having been exposed throughout the whole day to the action of the sun; and the eastern edge but now coming out of the night into it; the eastern and western edge cannot both be in the same condition. This produces an inequality; which is all we want: for a force will thence be generated in the Heavens on the western side, to propel the earth in its orbit. And with this direction in the earth the most ancient account of the creation seems to agree; where, in order of time, it sets the evening before the morning; which is proper, if the first impulse commenced at the western side of the earth. The greatest agitation of the day being on the West side of the meridian, there the power will chiefly act; and the earth will be moved toward that side where the action is weakest. But if this is to be effected by impulse, you may possibly observe, that it must require an immense impulsive force to carry forward with so much velocity a body of such magnitude is a planet. But in this we should argue like children; for though a planet be to our conception an immense unweildy body; it is well known to philosophical men, that a force, which in the beginning is leſs than any assignable quantity, may amount to any thing required, if it be added to itself by continual increments, like the power of gravity.

This, Sir, I must confess, is nothing more than a hasty sketch of one of the first and greatest operations in the universe; but of the principles in gross, on which it goes, I have no doubt. The forces employed in it are none of them petitionary; but real, and necessary, and adequate. I say they are necessary, because no motion can be continued in a *natural* way, if we suppose the first impulse to arise from any violent, artificial, or transient force. Because such a force, as I have already observed to you, always changes from more to less; whereas the forces of nature are from less to more. You have a familiar proof of this doctrine every time a body is thrown upwards. A violent force carries it up, which is greatest at first; a natural force brings it down, which is greatest at last. And I will venture to add, that if the earth could be stopt in its course, its motion, when the obstacle was removed, would be renewed on its own principles; because a body, situated under such circumstances as the earth is, cannot remain at rest.

Plain as these principles are, I will call him one of the most ingenious and knowing amongst mankind, who shall be able to collect the necessary data, so as to bring this affair to a calculation. The parallelism of the earth's axis, and the obliquity of the ecliptic, forming so nearly the same angle at all times with the equator, must require such a balancing of powers, as we can never hope to comprehend: nevertheless I can easily believe, that the powers, of which I have been treating, are adjusted with the utmost exactness to the intended effects. And to my understanding, it will always be more easy to conceive, how an effect of any kind may be brought to pass *with* natural means, than *without* them. The very eccentric motion of a comet is more agreeable to the effect of an electric power, than of any other power we are acquainted with. Who hath ever yet appeared to know what becomes of it in the superior part of its orbit? I would not depreciate the labours of learned men without some good reason. *Dr. Halley* bestowed much time and great labour in working upon the elements of cometary orbits, and thought he had reduced them to a system for the benefit of all posterity: but I believe it has never been found by experience, that they have been of any real use in astronomy. I have more satisfaction, and think it more to the purpose of physical astronomy, when I see a light body so nearly imitating (as it often happens) the motion of a comet about an electric conductor; first approaching, then partly surrounding, then flying off from it, without first falling into it. A phænomenon so similar directs us to a cause, better accommodated to the motion of a comet in the heavens, than any hitherto assigned by the learned.

So long as the natural world goes on in its regular course, (the moral world, God knows, is very much out of order) we ought to be thankful. But I sometimes figure to myself what may happen, if the solar system could suffer disorders, similar to those which befal the system of man's body; on a supposition that the sun is (as the ancients held it to be) the heart of heavens. When the capillary vessels at the extremities are stopt, the force of the heart is increased, the blood is accelerated in the arteries, and the effect is a fever. Thus if the circulation of the heavens could be obstructed at the orbit of Saturn, the force of the sun would be increased, and the earth would be whirled about with a swifter motion, which would tend to its dissolution. But while the powers of the heavens are justly balanced, according to the intention of the all-wise and beneficent Creator, the world is in health, and its revolutions are quiet and regular: we hear no confusion, we feel no disorder; but all goes on in silence for our good. Mankind are always desirous of penetrating farther into the wonders of the solar system. Telescopes, ever since the days of *Galileo*, have been constantly at work to explore new mysteries, which amaze and perplex man's understanding: and in consequence of this, we amuse ourselves with conjectures, with little prospect of finding out the ways of God to perfection. Different ages have gone upon different principles. Magnetism had its day: vortices were in great repute: gravitation (as a power *impressed* on matter) is now reckoned all-sufficient: but I think we stand at this time on fairer and firmer ground; Electricity having raised us to a point of view, where a new field is opened before us, of more promising speculation than was ever yet known to the world. But bright and open as the prospect may appear, we must never hope to keep clear of great difficulties and obscurities. In what I have now written to you, I must be content to partake of the common fate: on which consideration I must beg of you to accept with candour what I have offered to you in great friendship; and to add to, or correct my observations, as you shall hereafter find occasion. Slight and imperfect as my sketch may have been, I am persuaded that I have set before your eyes an idea of *the Solar System at work*, such as your mind will contemplate with new and increasing pleasure; and on which it will perhaps be hereafter employed, to your own amusement, and the improvement of other contemplative men. With this expectation I bid farewel for the present to you, as well as to this great and curious subject, and am,

Sir,

With great affection and esteem,

Your most obedient

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January 27, 1797.

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Page Wilkinson on [illegible] —

75.75 - 1 and 2 - Experiments in galvanism -

81 — 1 Fern leaves - Large quantity of Iron contained in them - wonderful power of vegetable combination

81 - 2 Calcareous Earth, Marble: Stones of various kinds &c, the astonishing origin of them; — - from Minute causes - what surprising effects! - the wonderful powers of an insect - Nothing created in vain! - What is Man? - How sublime an enquiring into the Operations of Nature & of Providence!

83 - (a) Potash & Soda or the Vege & Minl alkali a conjecture on their formation & origin

84 - b - Sulphur how formed. —

91 - a Law of action, & reaction, - ye if a cannon ball of a given Wt. moves a given No. of Feet, in a given time; - the Cannon whose Wt. is also known, will recoil or fly back, to a given point: - and thus the Wt. of the cannon, and its recoil being found, - and the Wt. of the ball being previously known - its velocity will appear, by the difference of its Wt. to that of the Gun, & the reaction it produces on it - .

116 Achromatic ~~[illegible]~~ Telescope the nature of them explained